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ECAC GUIDANCE on Sustainable Aviation Fuels (SAF)

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SAF are key for the transition to net zero aviation by 2050

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Sustainable aviation fuels (SAF) are a key enabler of the transition to net zero CO_2 aviation emissions by 2050 as per the long-term aspirational goal agreed at ICAO's 41st Assembly. With robust sustainability requirements, SAF could deliver both short- and long-term CO_2 emissions savings and help to address the non-CO_2 impacts of flying. Europe is a global frontrunner in policy action and industry voluntary initiatives to promote SAF, and the experience gained through those pioneering steps is a key asset to learn from and use to support others, either in Europe or beyond. We hope this guidance material facilitates technical understanding, policy development and harmonisation of best practices among ECAC States and with partners in other regions to build capacity and promote SAF globally.

Making the transition to SAF together

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In October 2022, at the 41st ICAO Assembly, countries took the historic decision to strive to achieve net-zero carbon emissions by 2050. Achieving this goal will be essential for aviation's licence to grow. As clearly showed in the report underpinning this decision, SAF will play a major role to achieve this goal. The SAF revolution has begun, and the EU will be part of it! Supply blending mandates will create market certainty for SAF production and uptake. Accompanying measures will improve SAF cost competitiveness, notably financial support for SAF development and uptake and industrial cooperation in the Renewable and Low Carbon Fuels Value Chain Alliance. In addition, a SAF clearing house pilot is foreseen to bring new SAF to the market and action within ICAO is important so that no country is left behind. I hope that this guidance will inspire countries across Europe to take bold actions to help the aviation sector achieve this transition successfully.

[1] This guidance does not constitute any formal commitment on behalf of the European Commission. The views expressed are purely those of the authors and may not be regarded as stating an official position of the European Commission.

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Corrigendum note:
This version was amended on 9 March 2023 to correct errors identified in Table 2 (page 25) and in paragraph 3.1 (page 37).

Executive Summary and Key Policy Recommendations

Showcasing the policy actions of pioneering European States and the European Union (EU)[2], as well as the initiatives of the European industry, is instrumental to successfully promoting Sustainable Aviation Fuels (SAF) throughout the ECAC region. At the same time, requirements should be harmonised as far as possible to avoid unnecessary barriers to the transition to SAF and complexity for economic operators. The regulatory initiatives taken in the last few years have paved the road for major developments to promote SAF in Europe.

Building on those experiences, this Guidance document is aimed at facilitating technical understanding, sharing information and best practices, and it also makes recommendations for designing policies to promote SAF in ECAC States, in the most harmonised manner possible.

What are SAF?

SAF stands for *Sustainable Aviation Fuels* that have very similar characteristics as traditional fossil jet fuel, but are produced from sustainable feedstocks[2]. They are available today and already in use by airlines, albeit in small quantities. SAF are “drop-in” jet fuels, meaning that they can be mixed with conventional fuels and are compatible with existing and future civil aircraft fleets and fuel infrastructures with, in principle, no need for any adaptation.

There are currently nine technology pathways (conversion process using non-conventional feedstocks) which have been approved as ‘drop-in’ Jet A1 for use in civil aviation with the same level of operational safety requirements. Additional pathways are under development or approval by the American Society for Testing and Materials (ASTM)[2].

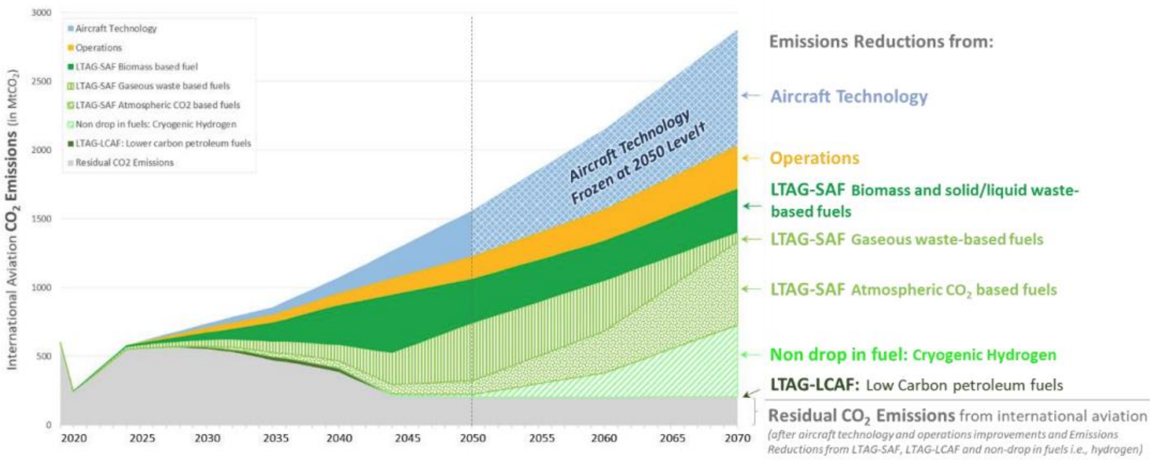
While not all of them are still sufficiently mature to produce SAF at industrial scale, SAF are already being produced and used today and numerous future production plants are expected in Europe and worldwide. Most (if not all) countries in the world have raw materials which potentially could be used for SAF production at commercial scale.

Why SAF are needed

The 41st ICAO[2] Assembly adopted a collective long-term global aspirational goal (LTAG)[2] for international aviation of net-zero carbon emissions by 2050 in support of the UNFCCC Paris Agreement's temperature goal, which consists in aiming to keep the global warming to well below 2°C, and preferably to 1.5°C, compared to pre-industrial levels.

[2] See Glossary

Extensive SAF use is expected to be the main measure driving the overall emissions reductions needed to achieve this ambitious goal, as identified in ICAO's analysis[3] developed by its Council's Committee on Aviation Environment Protection (CAEP)[4]. This is also consistent with the aviation industry's decarbonisation roadmaps[5]. The gap between the 2050 net-zero CO_2 emissions goal after technology, operations and infrastructure improvements will need to be mainly fulfilled through SAF, requiring significant amounts to be supplied to replace most of the conventional fuel.

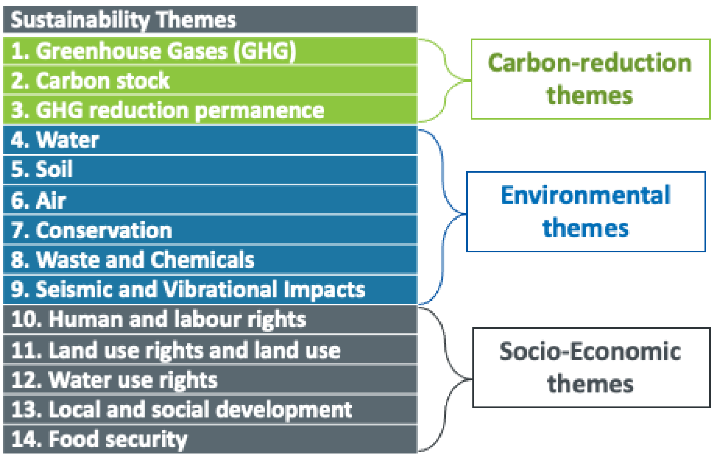


† Caution required with the interpretation of absolute CO_2 emissions levels after 2050 due to modelling assumptions e.g., frozen aircraft technology after 2050. Under these assumptions, CO_2 emissions are higher than in an alternative scenario (and modelling approach) where aircraft technology would continue to improve after 2050.

ICAO Report on the Feasibility of a Long-Term Aspirational Goal (Integrated Scenario 3).

As this huge transition will require time, there is a need to immediately start acting in every region and country on SAF development, in order to scale-up supply to achieve the net-zero CO_2 emissions goal.

Sustainability is a core requirement to safeguard credible carbon emission reductions and prevent unintended environmental and social impacts. For this, SAF should comply with globally recognised and verifiable sustainability criteria such as the CORSIA[4] SAF sustainability framework, covering 14 themes as shown in the figure. (In the EU, sustainability criteria are laid down in EU RED.)



In addition to tackling the climate crisis, SAF can be a means to **reduce energy and fossil fuels dependency** and diversify supply sources, which has become a European priority after the

[3] https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx
[4] See Glossary
[5] https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/

energy crisis caused by the Russian Federation's invasion of Ukraine in 2022. Whereas globally, 90% of fossil fuels come from only 22 countries today, most countries could become a SAF producer to different extents.

The transition to SAF has multiple other benefits. The development of SAF large-scale markets will need the expansion of new industrial capacity, generating jobs and economic growth. According to the Air Transport Action Group (ATAG), it is estimated that up to 14 million jobs could be created or sustained by the shift to SAF, all around the world.

Barriers and need for regulatory and policy action

The current largest barrier to wider SAF use is their higher cost of production. Both regulation and economic incentives are required to help bridge this price differential, drive demand, and generate greater predictability for investors and financiers.

In addition to the price gap, other identified challenges needing policy support are:

- **Technology readiness**: Investments in research, development, and demonstration to improve emerging feedstock production and conversion technologies, allowing for the use of a broader range of feedstock types and technologies.
- **Sectorial distribution**: Aviation is among the most difficult sectors to decarbonise thus making it paramount to channel limited SAF volumes.
- **Regulatory certainty and financial mechanisms**: Major investments in SAF plants will be needed, which requires predictable regulatory frameworks.
- **Level-playing field**: Avoiding undue distortion of air transport markets.
- **Harmonisation**: SAF reporting and claiming requirements, as well as fuel traceability rules, can be diverse under different jurisdictions and scopes, causing inefficiencies, risks of double or multiple claims and creating barriers.
- **Sustainability:** The deployment of SAF must ensure their sustainable production and use, reducing negative impacts on the climate and biodiversity while preventing pollution and reducing natural resources depletion.

The European SAF policy landscape

Several European States as well as the EU, have already taken policy actions to promote the supply and use of SAF. This guidance builds upon lessons learned from that experience. An overview of those, together with pioneering industry initiatives are publicly available in this document and shown on the European SAF map:

https://www.eurocontrol.int/shared/saf/

SAF potentials in Europe

The implementation of SAF policies in Europe can generate significant industrial opportunities. As an example, the ReFuelEU Aviation impact assessment[6] estimates that the

[6] Impact assessment available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=SWD:2021:633:FIN

EU could generate with its SAF mandate close to 100 000 net additional jobs in 2040 and around 200 000 in 2050.

Europe has a wide variety of feedstock and industrial potentials, which include generating SAF from non-recyclable wastes, residues, and non-food (lignocellulosic) crops as well as renewable fuels of non-biological origin (which encompasses Power-to-Liquid, electrofuels or Sun-to-Liquid), which are from renewable electricity and CO_2 sourced for example, from direct air capture.

Whilst scientific research referred to in this Guidance has concluded that the availability of sustainable feedstock may not be a major barrier to cover the potential European demand for SAF in 2030, as enough feedstock is present across Europe, a critical element will be the effectiveness of its sustainable mobilisation.

The ICAO Committee on Aviation Environmental Protection (CAEP) has developed a set of "*Rules of Thumb*" for SAF that could be utilised to make order of magnitude estimations related to SAF costs, investment needs and production potential.

Key Policy Recommendations

This SAF Guidance includes in its Section III recommendations for ECAC States to develop SAF dedicated policies and identifies different policy options or combinations of policies which can be used to support the development of a large-scale SAF market. The main policy recommendations include:

Create national SAF strategies and implementation plans

- ✓ Aviation decarbonisation strategies can be embedded in wider regional and global policies or regulatory frameworks.
- ✓ Before implementing SAF policies, it is recommended to first develop a coherent national SAF strategy, gathering data and analysing the specific context of each country, including, among others, feedstock, industrial and distribution potentials, existing and planned policy and regulatory frameworks (including, where applicable, at EU level).
- ✓ Create national multi-stakeholder platforms, tapping into the expertise and capabilities of feedstock producers/collectors, fuel producers, traders and suppliers, investors, original equipment manufacturers (OEMs), airports, airlines, civil society organisations, etc.

Develop national SAF roadmaps or transition pathways. Set targets and give certainty in order to mobilise investments.

- ✓ Medium to long-term policy and regulatory certainty are key to influence market expectations and incentivise investments. This can be provided by setting a national policy vision, which includes the definition of targets and ambitions (including, where applicable, at EU level).

- ✓ Creating roadmaps or transition strategies has been another valuable common practice in pioneering European States, in most cases embedded in wider national climate policies and objectives. The main final purpose of this approach should be informing policymakers on the necessary actions that are needed to incentivise SAF and mobilise investments into SAF research, development, and pilot production.
- ✓ When developing a national SAF roadmap or transition pathway, consider market competition including with other regions and sectors, local singularities, and ensure a level playing field avoiding any barriers or distortion to competition.

Ensure sustainability with credible emission reductions and build social trust

- ✓ Any SAF strategy should ensure environmental and social integrity and supply chain verification, to maximise CO_2 emission reductions and prevent unintended environmental and negative socio-economic effects. This includes issues like GHG emissions, biodiversity loss, pollution and depletion of natural resources.
- ✓ Harmonisation of compliance requirements will help avoiding barriers for SAF deployment and use.
- ✓ To maximise climate benefits, it is recommended that policies consider the quantity of CO_{2eq} (significant reductions in GHG (expressed as CO_{2eq}) emissions reductions rather than only the volume of SAF (with different CO_{2eq} emissions reduction potentials).
- ✓ Avoiding any misleading information and communication strategies related to SAF use and trading as well as avoiding fraud, are necessary as well to build trust in the benefits of SAF use.

Select the most suitable policy or combination of policy options

The most suitable policies to promote SAF are likely to vary across countries according to their geographic, economic, social, and political characteristics (e.g. if the country is a member of the EU or not). No individual policy is likely to drive SAF growth on its own. Policymakers are invited to use the information contained in Chapter 6 of this Guidance and the Recommendations in Section III, to support decision-making regarding policy options.

- ✓ Eight qualitative metrics extracted from the ICAO *Guidance on potential policies and coordinated approaches for the deployment of SAF,* can be used by States for assessing policy effectiveness.
- ✓ It is recommended to set policies which are technology-neutral to enable diverse production pathways and supply chains to develop.
- ✓ It is necessary to seek a balance between demand and supply side policies to preserve market equilibrium and avoid possible carbon leakage[7]. Ideally, a balanced policy framework should plan and implement both supply and demand measures, with coordination and planning for when each policy will enter into force.

Stimulating growth of SAF supply can be achieved, among other options, via:

- funding and promoting SAF research, development and demonstration;

[7] See Glossary

- de-risking first-of-a-kind SAF production plants;
- supporting the expansion of SAF infrastructure and high technology readiness level pathways; and
- stimulating sustainable feedstock for SAF production & optimising conversion yields.

Stimulating SAF demand can be achieved, among other options, via:

- updating existing national policies and creating/implementating SAF blending mandates;
- incorporating social and environmental costs in the price of conventional jet fuel; and
- demonstrating government leadership and including SAF in public procurement.

Additional policy measures can **facilitate SAF markets**, such as:

- establishing flexible logistic mechanisms for the SAF transition and virtual SAF marketplaces;
- supporting SAF stakeholders' initiatives, where appropriate;
- capacity-building to promote SAF production; and
- Including adequate enforcement mechanisms.

Introduction

The 2019 ECAC Environmental Forum highlighted the need for sharing best practices and experience on supporting policies for the development and deployment of sustainable aviation fuels (SAF), following a request by several ECAC Member States and the European industry.

Information sharing on SAF-related policy plans and actions taken by different ECAC States, as well as European recommendations when developing national policies, adds to the industrial and economic ability to successfully promote SAF across the ECAC region.

On the basis of agreements within ICAO including its global Assistance, Capacity-building[8] and Training for Sustainable Aviation Fuels (ACT-SAF) programme, an increasing number of ECAC Member States are taking policy actions to promote the large-scale development and supply of SAF and have established or are in the process of developing national SAF-promotion policies.

In the case of EU States, the European Commission[8] proposed on 14 July 2021, a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport (the ReFuelEU Aviation Regulation). The proposal and the ensuing EU inter-institutional process leading up to the adoption of the Regulation will be the regulatory measure for promoting SAF in the EU.

The ECAC Directors General agreed to include in ECAC's Environmental Programme (DGCA/155-DP/9) the development of guidance to promote technical understanding, best practices, and harmonised policies to support SAF promotion in ECAC States. An ad-hoc Sustainable Aviation Fuels Task Group (SAF-TG) was created in November 2021 under the aegis of the European Aviation and Environment Working Group (EAEG) Expanded.

The SAF-TG, with co-rapporteurs from Spain and the European Commission, was formed by experts from different ECAC States and European organisations with a wide geographical representation and characteristics in terms of national aviation market contexts. This guidance is the result of their technical work and it is addressed both to those ECAC States who might consider developing SAF promotion policies and to those who are already in the process of implementing them.

This ECAC guidance is divided in three sections:

Section I: Setting the SAF scene

Setting the scene includes general information on SAF and on the European context, through the following chapters:

1. Background: What are Sustainable Aviation Fuels (SAF) and why are they needed?
2. The European SAF landscape

[8] See Glossary

3. SAF potentials and benefits in Europe

Section II: Developing SAF policies

This Section contains SAF policy guidance and recommendations to ECAC States' policymakers, based on the work of the SAF-TG and on the adaptation to the European framework of the Clean Skies for Tomorrow (CST) *SAF Policy Toolkit*, undertaken in cooperation with CST, including:

1. Considerations for creating a SAF strategy
2. Policy options to support the development of a scaled SAF market

Section III: Key policy recommendations

Section III includes recommendations for ECAC States to develop dedicated and harmonised SAF policies and identifies different policy options or combinations of policies which can be used to support the development of a large-scale SAF market.

The Guidance also contains a final **Conclusion** chapter, followed by a **Glossary** and a **Bibliography** .

It should be noted that this ECAC Guidance has considered other available SAF guidance, when developing this document and the recommendations in it, and notably:

ICAO Guidance material

ICAO issued in June 2022 a *Guidance on potential policies and coordinated approaches for the deployment of SAF*, developed by the ICAO Committee on Aviation Environmental Protection (CAEP), intended as a support reference for ICAO Member States seeking to develop SAF production or part of the SAF supply chain such as feedstock production. It provides examples of SAF policy approaches being utilised and considered around the world. Technical work on an update has been completed and a new edition is expected soon.

The Clean Skies for Tomorrow (CST) SAF Policy Toolkit

In April 2022, the SAF-TG agreed to cooperate with the Clean Skies for Tomorrow (CST)[9] initiative and consider its *SAF Policy Toolkit* which draws from the experience and diversity of the CST SAF Ambassadors group and a wider CST community.

International Transport Forum (ITF)

The SAF-TG has also considered recommendations emerging from discussions among the members of the OECD International Transport Forum (ITF)'s Decarbonising Aviation Common Interest Group (CIG), created in June 2021 funded by the European Commission, and co-chaired by Norway and Sweden.

[9] CST is a global public-private partnership led by the World Economic Forum in collaboration with the Rocky Mountain Institute and the Energy Transitions Commission, with stakeholders working collectively to advance the commercial scale of SAF, in collaboration with the CST SAF Ambassadors, comprising the governments of Kenya, the Netherlands, Singapore, the United Arab Emirates and the UK.

Section I — Setting the SAF scene

1. Background: What are SAF and why are they needed?

1.1. SAF definitions

There is not a single internationally agreed definition for Sustainable Aviation Fuel (SAF), but the existing references in different policy or regulatory frameworks refer to a non-conventional drop-in[10] aviation fuel, alternative to fossil-based jet fuel that reduce life cycle green-house gas (GHG) emissions[11] relative to conventional aviation fuel, and which are compliant with certain sustainability requirements to avoid other adverse environmental and socio-economic impacts. In the EU, such requirements are specified in the Renewable Energy Directive in force, which includes a detailed set of sustainability criteria for biofuels, covering GHG emissions reductions, preservation of biodiversity, land-use impacts, amongst other criteria. The European Aviation Environmental Report (EAER) 2022[12] contains a full chapter dedicated to SAF.

The two key requirements that any SAF should accomplish are:

- To be ***Sustainable***: Need to fulfil specific sustainability requirements, including greenhouse gas (GHG) emissions reductions, defined in an explicit policy/regulatory framework or standard; and .
- To be ***Aviation Fuel***: Need to meet equivalent aviation fuel specifications as existing fossil-based ones, be “drop-in” or miscible thus compatible with existing and going into service civil aircraft fleets.

Definitions of SAF vary considerably across the globe. There are significant differences when it comes to greenhouse gas emissions reduction thresholds and other environmental and/or social criteria. To illustrate this point, examples of SAF definitions which can be found in existing policy frameworks are detailed below.

It should be noted that the different definitions of what is SAF under the different regulatory jurisdictions would have an impact over the eligibility of different types of SAF and their mutual recognition. This will be addressed in more detail in Section II of this document.

- **ICAO Annex 16 Volume IV (CORSIA Standards and Recommended Practices)**: *Sustainable aviation fuels (SAF) are renewable or waste-derived aviation fuels that meets sustainability criteria*.

[10] They have to meet similar strict fuel specifications as conventional fossil-based fuel, be mixable with it and have comparable behaviour to conventional aviation fuel to be used without modification of existing aviation fleets.

[11] See Glossary

[12] https://www.easa.europa.eu/en/newsroom-and-events/press-releases/european-aviation-environmental-report-2022-sustainability

Sustainability criteria used in ICAO for determining eligibility under CORSIA requires net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values, comprising direct and indirect land-use change emissions, that it is not made from biomass obtained from land with high carbon stock and that it meets additional criteria in the areas of water, soil, air, conservation, waste and chemicals, human and labour rights, land use rights and water use rights, local and social development and food security, as defined in the ICAO document: *CORSIA Sustainability Criteria for CORSIA Eligible Fuels*[13].

CORSIA Sustainability Criteria is the first globally agreed[14] sustainability meta-standard[15] applied to an energy sector. While the current 10% GHG reduction threshold is considered from the European perspective small, it is worth noting that both direct emissions and indirect land-use change emissions concur to defining SAF eligibility. In this sense, CORSIA incentivises the use of those fuels with higher emissions reductions on a Life-Cycle assessment (LCA)[17] basis and most of the pathways for which a specific default value has been calculated under the scheme have the potential to achieve significantly higher reductions, while also complying with sustainability criteria laying outside the mere consideration of GHG performance.

- **ReFuelEU Aviation Initiative[16]**:

Under the ReFuelEU Aviation proposal, fuels would need to meet net greenhouse gas emissions reductions of at least 65% in order to be considered SAF, and in addition, meet sustainability criteria aligned with the EU Renewable Energy Directive (EU RED) and furthermore excluding fuel derived from feed and crop-based feedstock (whose use is capped in the RED) thus considering indirect land use change through a risk-based approach and not via quantified yet uncertain values.

'SAF' means drop-in aviation fuels that are either synthetic aviation fuels[17], advanced biofuels as defined in Article 2, second paragraph, point 34 of Directive (EU) 2018/2001[18]*(* Renewable Energy Directive, so-called EU RED*) or biofuels produced from the* feedstock *listed in Part B of Annex IX to that Directive, which comply with the sustainability and greenhouse gas emissions criteria laid down in Article 29(2) to (7) of that Directive and are certified in accordance with Article 30 of this Directive. GHG reduction criteria is set at 65% to align with existing legislation and to align across the transport sectors.*

'Synthetic aviation fuels' means fuels that are renewable fuels of non-biological origin, (RFNBO) *as defined in Article 2, second paragraph, point 36 of Directive (EU) 2018/2001, used in aviation. GHG reduction criteria is set at 70% compared to the baseline.* However, the co-legislators, i.e. the European Parliament and the Council of the EU, have both proposed somewhat different definitions of SAF.

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[13] https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx
[14] https://www.sciencedirect.com/science/article/pii/S1364032121006833
[15] It does not establish a new standard as such: builds on existing standards (Such as ISCC and RSB) and provides guidance to verifiers/certifiers.
[16] as per the Regulation proposal, subject to changes during the legislative process still open at the date of issuing this document.
[17] See Glossary
[18] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG – Article 29, 10 (c)

- **Norway SAF mandate:**

Norway was the first country worldwide with a mandate for aviation; an obligation to blend in 0.5% advanced biofuel, in operation from January 2020. The Norwegian mandate has the following sustainability requirement: To be made from feedstocks listed in Part A and Part B of Annex IX of the Directive (EU) 2018/2001 (EU RED). SAF net greenhouse gas emissions reductions requirements are aligned with the EU RED, which is regulatory text of EEA relevance that Norway reflects in its national regulatory framework.

- **UK SAF Mandate Consultation Government Response (2022)[19]:**

The UK SAF mandate consultation referred to *'SAF'* as *alternative, sustainable jet fuel replacements that could be blended into existing aircraft without significant engine modifications.*

In the government response to the consultation on a SAF mandate, the UK set out their aim to deliver fuels with the highest sustainability credentials while maintaining appropriate safety standards. Therefore, as proposed in the original consultation, to receive credits under the mandate SAF will be required to:

- meet the requirements set out in the *DEF STAN 91-091* specification[20];
- be waste-derived biofuels, power-to-liquid (PtL) or recycled carbon fuels (RCFs), where PtL fuels must use either renewable or nuclear energy sources;
- comply with the waste hierarchy when derived from wastes;
- achieve at least a 50% GHG saving compared to a fossil fuel comparator of 89 gCO2e/MJ (a final minimum GHG savings threshold is still to be decided);
- meet land criteria when derived from agricultural wastes and meet forestry criteria when derived from forestry wastes; and
- use low carbon hydrogen where hydrogen is used as an input which contributes to fuel's energy content.

Certain aspects of this sustainability criteria are still being developed and will be consulted upon further in a second consultation in 2023.

- **United States of America regulations**

While the US does not currently have a SAF blending mandate, they do provide tax credits for SAF under the Inflation Reduction Act. To qualify for the credit of USD 1.25 for each gallon of SAF, the SAF must have a minimum reduction of 50% in lifecycle greenhouse gas emissions. Additionally, there is a supplemental credit of one cent for each percent that the reduction exceeds 50%.[21].

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[19] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1100050/sustainable-aviation-fuels-mandate-summary-of-consultation-responses-and-government-response.pdf

[20] See Glossary

[21] https://www.irs.gov/newsroom/treasury-irs-issue-guidance-on-new-sustainable-aviation-fuel-credit

- **Voluntary Standards**

Beyond national, regional and international regulatory provisions, voluntary standards such as the Roundtable on Sustainable Biofuels (RSB) and the International Sustainability and Carbon Certification (ISCC) have developed standards in line with existing regulatory requirements, setting GHG reduction levels at a minimum 65% in line with the EU requirements applicable in 2022.

1.2. SAF qualification and clearing houses

In 2022, the main specifications for civil aviation Jet A-1 fuel are the UK specification DEF STAN 91-91 and the American Society for Testing and Materials (ASTM) specification D1655. There are many national and international jet fuel specifications, some of which have been created by nation states desiring their own specification. However, as jet fuel is an internationally traded commodity these specifications are essentially the same and generally follow either DEF STAN and/or ASTM requirements.

Any new aviation fuel such as SAF must meet equivalent fuel specifications as existing fossil-based ones, be miscible up to specific blending grade(s) with them, have equivalent physicochemical structure and behaviour, comply with global standards and have at least the same level of operational safety requirements as conventional fuels in order to ensure compatibility with its use on existing and future civil aircraft fleets (what is commonly referred to as “drop-in” fuels).

In June 2009, ASTM International issued the ASTM D7566[22] Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons.

It is currently the reference at global level for new alternative fuel pathways (conversion process and associated possible feedstock) to be approved for safe use in aviation. The UK DEF STAN standard incorporates the requirements approved by ASTM International.

An overview of the aviation fuel approval process is provided in Chapter 3.1 of EASA’s[23] Sustainable Aviation Fuel ‘Facilitation Initiative’ Study[24] (November 2019) that examined how to incentivise the approval and use of SAF as drop-in fuels in Europe. The paragraphs below are an excerpt from such work.

ASTM D7566 has evolved to meet the challenge of introducing new feedstock types, processing and blend ratios that are compatible with airport fuel distribution systems and civil aircraft fleets.

New pathways are assessed against the ASTM D4054[25] Standard Practice and, once approved, each suitable pathway is later included within ASTM D7566. Each Annex in ASTM D7566 is linked to a specific feedstock type list, conversion process and maximum blending level.

22 https://www.astm.org/Standards/D7566.htm

23 See Glossary

24 https://www.easa.europa.eu/document-library/research-reports/grant-agreement-easa2015fc21-0

25 https://www.astm.org/d4054-21a.html

SAF blending and certification

Importantly, once produced and blended in compliance with ASTM D7566, the fuel is then designated as ASTM D1655 Jet A or Jet A-1 and handled as per conventional fuel.

Figure 1 below illustrates the current ASTM D7566 certification process requiring blending with fossil JetA1. The current existing technology processes defined in ASTM D7566 (See Table 1 in Section 1.3 below) require blending with fossil JetA1 (D1655 Certified).

There are currently new processes which will not need such blending.

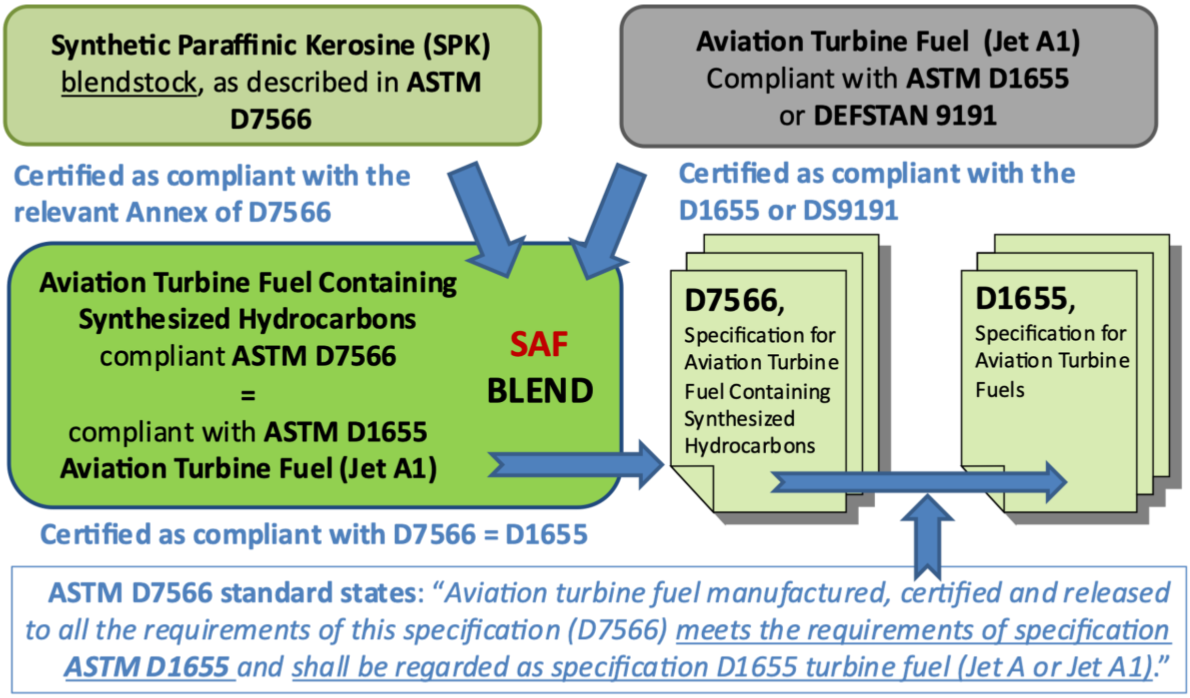

Figure 1: SAF certification process in compliance with ASTM D7566 (Source: SAF-TG)

SAF quality assurance and logistics

This specification does not define the quality assurance testing and procedures necessary to ensure that fuel in the distribution system continues to comply with this specification after batch certification. Such procedures are defined for example in ICAO 9977, EI/JIG Standard 1530, JIG 1, JIG 2, API 1543, API 1595, and ATA-103.

JIG (Joint Inspection Group) develops a set of standards for the operation and handling of jet fuel at shared airport facilities and maintains the Aviation Fuel Quality Requirements for Jointly Operated Systems (AFQRJOS), containing the most stringent requirements from both ASTM D1655 and DEF STAN 91-91. When defining the point of blending the synthetic blendstock (SPK)[26] with conventional fuel, it is important to consult all those standards, in order to avoid problems in the fuel handling and the logistics chain. I.e. DEF STAN 91-91 indicates that the location at which a semi-synthetic aviation turbine fuel is blended shall be upstream of the airport fuel storage depot, with some controlled exceptions (issue 14).

[26] See Glossary

Also, the use of NATO storage and distribution facilities by jet fuel blended with synthetic components is subject to express approval by competent authorities as referred in the norm: *before fuel containing synthetic components may be delivered to a NATO aircraft it shall be ascertained that the appropriate clearance document(s) permitting its use have been obtained according to contract. This may restrict supply of fuel containing synthetic components in some pipeline systems with direct connections to NATO storage locations* (JIG AFQRJOS-issue 33).

Evaluation and approval of new SAF pathways

Extensive testing on the blend stock and final blend grade(s) is required to ensure the fuel is fit for purpose and performs within expected norms. Any new SAF must be evaluated and approved before its inclusion within ASTM D7566 standard (as a new Annex), in accordance with the principles established in Practice ASTM D4054.

In summary, D4054 is a tiered process that requires testing with increasing complexity, scale and therefore economic costs:

- Tier 1 - Basic standard specification testing;
- Tier 2 - Fit for Purpose testing which includes mainly laboratory scale testing of a wider range of properties, compositional analysis (bulk and trace), material compatibility and performance properties, etc;
- Tier 3 – Rig scale testing to assess behaviour under simulated airframe and/or engine conditions to cover such parameters as thermal stability, cold flow, combustion under adverse conditions (operability), etc; and
- Tier 4 – Full engine testing to assess impact on performance, durability, emissions, etc.

Figure 2 below summarises the ASTM D4054 Qualification process and is sourced from the US Commercial Aviation Alternative Fuels Initiative (CAAFI)[27] webpage.

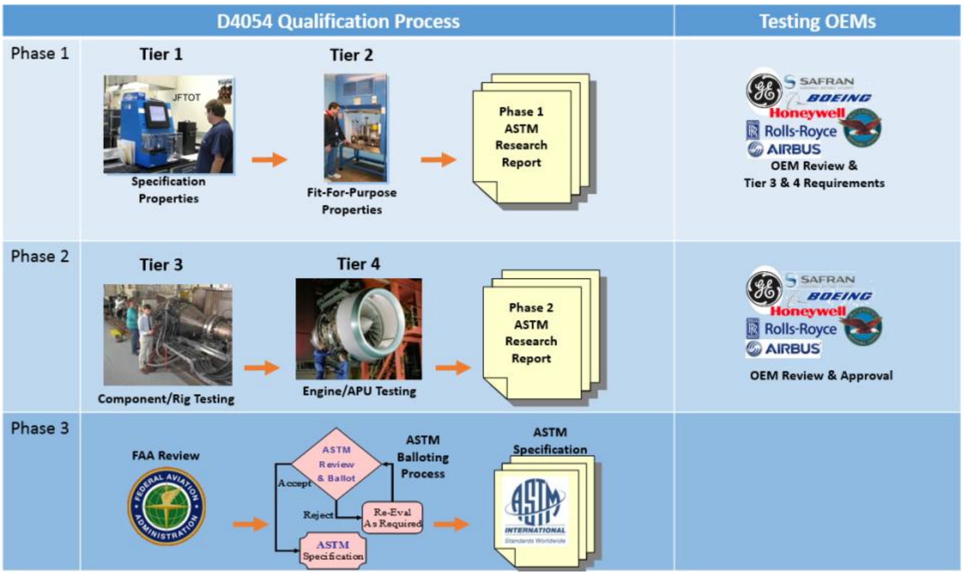

Figure 2: ASTM D4054 Qualification process (Source: CAAFI)

27 https://www.caafi.org/focus_areas/fuel_qualification.html

The process to get a novel blend-stock[28] approved can be a complex, costly and lengthy one, that requires the attributes of a high level of technical expertise, access to specialist test facilities and positive and coordinated engagement with key industry stakeholders.

Recognising the barrier posed by the difficult approval process, the US set up a D4054 'Clearing House'[29] which provides advice and support on the approval process, carries out and/or coordinates the necessary tests required and funds Original Equipment Manufacturers (OEMs) to review the research report produced based on the tests done (as required by the D4054 standard). This Clearing House is funded by the Federal Aviation Administration (FAA)[29].

An EU *Clearing House*

The EU funded JETSCREEN project[30] (2017-2020) proposed new procedures[31] for pre-screening and assessment of new SAF candidate fuels before entering the official ASTM D4054 evaluation process.

Additionally, the above referred 2019 EASA SAF "Facilitation Initiative" study recommended the creation of an EU Clearing House[29], modelled on the US Clearing House and carrying out similar activities. The European Parliament has attributed funding for the preparatory action to assess the feasibility of such an EU Clearing House, which is identified among the flanking measures to the ReFuelEU Aviation legislative proposal (see Annex 6 of Impact Assessment). EASA has been subsequently contracted to manage this project and the work on the EU Clearing House is planned to start during the first half of 2023.

On this subject, it is also worth noting that the EU supports H2020 TULIPs Green Airports project[32] containing a specific task on a Clearing House, aiming at drafting a proposal for a structure of an EU Clearing House. The task and the initiative is coordinated by the Politecnico di Torino.

The primary objective of these actions is to set up a new European technical capability to provide SAF approval solutions via an *EU Clearing House for Sustainable Aviation Fuels (SAF)*. It would cover the definition, validation, and test of the concept to be implemented in Europe by setting up the required European capabilities and tools.

The main responsibilities of a Clearing House for SAF could be summarised as follows:

- Pre-screening and advising fuel producers on their fuel and production process, to increase the likelihood of producing a commercially viable SAF.
- Develop and implement procedures for fuel producers to go through the fuel certification and approval process, including the partial funding of fuel testing and research report review costs. This includes the following activities:

28 See Glossary

29 https://ascent.aero/publication/astm-d4054-clearinghouse/

30 https://cordis.europa.eu/article/id/429445-fuelling-the-future-of-aviation

31 *Sustainable aviation fuel prescreening tools and procedures*. Published in:Fuel, Issue 290, 2021, Page(s) 120004 (2021)

32 https://tulips-greenairports.eu/

  - Determining the required tests, arranging testing with participating testing facilities, coordinating the shipment of fuels to testing sites, interpreting results and related data and information.
  - Coordination with testing facilities and OEMs to produce research reports, and organisation of the report review process with OEMs and specification bodies.
- Assisting producers – including those following approved production processes – through all stages of product development, from early assessment to ongoing due diligence testing.
- Contributing to efforts to streamline the existing fuel certification process without compromising product performance and safety.
- Advise on options for obtaining appropriate sustainability certification.

A study conducted by EASA[33] has shown that EU-based labs possess all the required capabilities to carry out the relevant tests for the early stages of certification of a novel SAF (up to Tier 2 of the D4054 process). This capability is split across several facilities and this geographical spread of testing capability in Europe presents another prospective benefit for an EU Clearing House. For a fuel producer navigating the certification process, the Clearing House would offer a single point of contact and would handle all contacts with the relevant testing facilities, in addition to ensuring proper delivery of fuel samples.

Potential benefits of a Clearing House include:

- **Increase the variety of feedstocks and pathways** suitable for SAF production to:
  - **De-risk supply** by accelerating approval of production options as demand rapidly grows. This is especially important if customers begin to expect airlines to set ambitious SAF targets, accelerating industry change faster than policymakers or the industry might currently plan.
  - **Increase competition and decrease costs**.
  - **Decrease CO_2 emissions in the production process** i.e. to bring to market pathways with lower production and combustion emissions than those used today.
  - **Ensure that SAF do not harm biodiversity, or contribute to pollution and resources depletion,** ensuring comprehensive environmental sustainability.
- **Increase blending rates**: Different pathways will be suitable for blending at different rates while maintaining overall fuel properties within safe limits. New pathways offer the option for higher blending rates which will be important to meet SAF mandates and in-sector decarbonisation targets as they exceed existing blending limits.
- **Potential testing of additives:** Additives are not currently eligible for any of the services provided by the US Clearing House. As SAF use rises over time, the role of additives may become increasingly important. An EU Clearing House could support

33 https://www.easa.europa.eu/sites/default/files/dfu/sustainable_aviation_fuel_facilitation_initiative_0.pdf

additive testing and approval in addition to SAF activities. This could be especially relevant in the EU as many major additive producers are EU based.

- **Dependable system for EU producers:** As the number of prospective SAF producers increases, demands on the US Clearing House are increasing, which could lead to a bottleneck in future. An EU Clearing House would avoid that.

Close cooperation with the US Clearing House and other similar initiatives would ensure the efficient use of resources and avoidance of duplication or competition, exploit each entity's strengths, with bodies collectively augmenting the global capacity to approve new SAF and thus acting as key enablers in the decarbonisation of the aviation industry.

A UK *Clearing House*

In the UK government's Ten Point Plan for a Green Industrial Revolution from 2020, the UK committed to establishing a SAF clearing house to support sustainable aviation fuel testing and enable the certification of new fuels. This commitment was restated in the 2022 Jet Zero Strategy, recognising that support for testing is essential to help reduce barriers to SAF development and broaden the scope of eligible fuels to support aviation decarbonisation.

The key objectives of the UK Clearing House are to:

- enable testing and certification of SAF in the UK to Tiers 1 & 2, and Tiers 3 & 4 (of the D4054 process) on a case-by-case basis;
- de-risk the testing process for SAF producers;
- accelerate market entry of new advanced fuels to support our 10% SAF by 2030 target;
- signal the UK's commitment to building a thriving domestic SAF industry; and
- collaborate with other Clearing Houses to share data and support global SAF development.

A procurement process is underway to appoint a delivery partner to finalise the design, set up and operate the UK Clearing House, which is expected to become operational in 2023.

1.3. Technology options

1.3.1. Approved SAF technology pathways

When this Guidance was published there were nine major technology pathways of 'drop-in' jet fuels from non-conventional feedstocks approved for use in civil aviation, which can be blended or co-processed at a certain percentage with conventional Jet-A1. Seven of them are defined by the following ASTM D7566 Annexes. Once the ASTM D7566 certified blendstock is blended with fossil fuel and re-certified, it meets ASTM D1655 Jet A or Jet A-1 requirements (see **Figure 1** above) and can be handled as conventional fuel.

In addition, up to 5% volume of fats and oils, or 5% volume of synthetic crude produced from a synthesis gas (or syngas[34]) in a Fischer-Tropsch process[35], can be co-processed in a conventional refinery to produce kerosene and be certified under Annex A1 of ASTM D1655.

Table 1 below summarises the status of existing technology options and standards:

ASTM D7566	PROCESS	APPROVAL DATE	BLEND RATE	POSSIBLE FEEDSTOCKS
Annex A1	Fischer Tropsch (FT) Synthetic Paraffinic Kerosene (**FT SPK**)	2009	Up to a 50%	Cellulosic biomass and Municipal Solid Waste
Annex A2	Hydro-processed Esters and Fatty Acids (**HEFA SPK**)	2011	Up to a 50%	Lipids (such as oils, fats and greases)
Annex A3	Hydro-processed Fermented Sugar (**HFS-SIP**)	2014	Up to a 10%	Sugars
Annex A4	Synthesized paraffinic kerosene plus aromatics (**FT-SPK/A**)	2015	Up to a 50%	Cellulosic biomass and Municipal Solid Waste
Annex A5	Alcohol to Jet (**ATJ-SPK**)	2016 for isobutanol; updated in 2018 for ethanol	Up to a 50%	Ethanol and isobutanol that can be derived from starch and sugars, cellulosic biomass, waste gases fermentation
Annex A6	Catalytic Hydrothermolysis (**CHJ**)	2019	Up to a 50%	Lipids (such as oils, fats and greases)
Annex A7	Hydroprocessed Hydrocarbons, Esters and Fatty Acids Synthetic Paraffinic Kerosene (**HHC-SPK or HC-HEFA-SPK**)	2020	Up to a 10%	Bio-derived hydrocarbons (at present only produced by algae), fatty acid esters, and free fatty acids.
ASTM D1655	**PROCESS**	**APPROVAL DATE**	**RATE**	**FEEDSTOCK**
Annex A1	**Co-processing** of esters and fatty acids in a conventional petroleum refinery	2018	Up to a 5%	Lipids (plant oils and animal fats)
Annex A1	**Co-processing** of Fischer-Tropsch hydrocarbons in a conventional refinery	2020	Up to a 5%	Fischer-Tropsch Biocrude (unrefined hydrocarbon content from a FT reactor)

Several new technology pathways are currently following the D4054 qualification process. Updated information can be found in the US CAAFI[35] website.

34 See Glosary

35 https://www.caafi.org/focus_areas/fuel_qualification.html

1.3.2. SAF of non-biological origin

As referred in Chapter 1.1 (SAF definitions), the EU has defined '*Synthetic aviation fuels' as* fuels that are Renewable Fuels of Non-Biological Origin, also referred as RFNBOs[36], but in other jurisdictions can have different definitions.

While these types of fuels are not yet commercially available, some European national and regional policies are promoting their upscaling which will be needed to fulfil the decarbonisation roadmaps of hard to abate transportation modes, including aviation.

Note that synthetic aviation fuels are also commonly denominated as electro-fuels, e-Fuels, Power-to-Liquid (PtL) or aviation fuels with significant electricity inputs.

Another type of fuel of non-biological origin is produced with the Sun-To-Liquid[37] technology, which uses concentrated solar radiation to drive a thermochemical process.

Sun-to-Liquid solar plant in Mósteles (Spain). Source: DLR. Photo: ©ARTTIC 2019

All those fuels are made from renewable sources other than (sustainable) biomass. These can be of solar, wind, geothermal and hydropower origin, and use as feedstock H_2O and CO_2, from direct air capture (DAC). CO_2 could also be sourced from industrial gases –see also Ch.1.3.3.

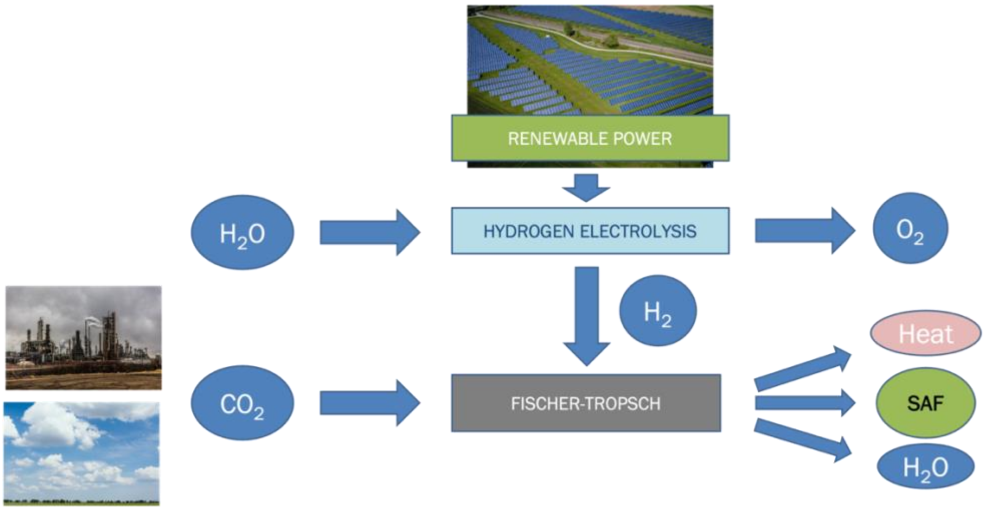

Figure 3: Power-to-Liquid (PtL) production inputs and outputs. Source: SAF-TG

36 RED, Article 2, (36) 'renewable liquid and gaseous transport fuels of non-biological origin' means liquid or gaseous fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass.

37 https://www.sun-to-liquid.eu/

Power-to-liquids (PtL) could emerge as a critical pathway as aviation shifts from fossil to sustainable aviation fuels. The Clean Skies for Tomorrow (CST) initiative, has investigated how it could be scaled in the decade ahead, including how production could unfold in a range of scenarios.

Their report *Delivering on the Global Power-to-Liquid Ambition*[38] is intended to inform the decisions of governments, policy-makers, industry and investors, all of whom will be critical in seizing opportunities, overcoming challenges and taking action to increase the production and use of PtL to reach net-zero emissions goals by 2050.

Synthetic aviation fuels can also be produced using power from nuclear energy, so-called low-carbon fuels (LCF)[39], which are also of non-fossil, non-biological origin, but not RFNBOs.

1.3.3. Recycled Carbon Fuels

Recycled Carbon Fuels (RCF) are different to renewable fuels in that they are produced from fossil wastes (solid, liquid, or gaseous waste streams) that cannot be prevented, reused, or recycled and would otherwise be landfilled, incinerated, or released to the environment. Examples of feedstocks include the fossil fraction of municipal solid waste (MSW) (e.g. non-recyclable plastic) and industrial fossil wastes or off-gases from steel works.

Although not being renewable fuels, RCF can be a potential feedstock source for synthetic aviation fuel. Supporting RCF can lower the average GHG intensity of jet fuel and encourage the innovation needed to increase deployment of low carbon fuels in transport sectors that are more challenging to decarbonise, such as aviation.

The UK government published a consultation in July 2022[40] which outlined proposals for introducing support for RCF under the Renewable Transport Fuel Obligation, which can be a reference for other States.

1.4. SAF Benefits: Why are we promoting them?

1.4.1. Approaching aviation's climate ambitions

SAF is one element of the ICAO basket of measures to reduce aviation emissions, which also includes technology and standards, operational improvements, and market-based measures, i.e. the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Since 2009[41], ICAO, its Member States and the aviation industry have recognized the use of SAF as an important means of reducing aviation emissions and reducing aviation's dependence on fossil fuels. Since then, ICAO Member States have been encouraged to establish policies that support the use of SAF.

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[38] https://www.weforum.org/reports/clean-skies-for-tomorrow-delivering-on-the-global-power-to-liquid-ambition/

[39] See Glossary

[40] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1097039/supporting-recycled-carbon-fuels-through-rtfo.pdf

[41] First ICAO Conference on Aviation and Alternative Fuels, Rio de Janeiro, Brazil (16 to 18 November 2009)

The 41st ICAO Assembly adopted a collective long-term global aspirational goal (LTAG) for international aviation of net-zero carbon emissions by 2050 in support of the UNFCCC Paris Agreement's temperature goal. This global aviation climate goal is included in ICAO Resolution A41-21[42].

This agreement was based on a feasibility study of a long-term global aspirational goal for international aviation, developed by the Council's Committee on Aviation Environment Protection (CAEP), which consolidated cumulative efforts of over 280 experts over nearly two years of intensive work.

The agreement was also preceded by a variety of 2050 decarbonisation initiatives, including the Toulouse Declaration[43], The Waypoint 2050 report[44] by the International Air Transport Association (IATA) and the Air Transport Action Group (ATAG) in 2021, and the Destination 2050 report[45] focused on the European aviation sector, exploring how the sector may be able to meet such a goal and the fundamental role of SAF.

CO_2eq emissions reductions

SAF can offer significant reductions in GHG (expressed as CO_{2eq}) emissions on a life-cycle basis compared to conventional fossil jet fuel, depending on the origin and type of feedstock and the production technology option used, as reflected in the ICAO Document *CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels*. For the EU, the Renewable Energy Directive includes in its Annex a comparator providing the GHG emission reductions for biofuels.

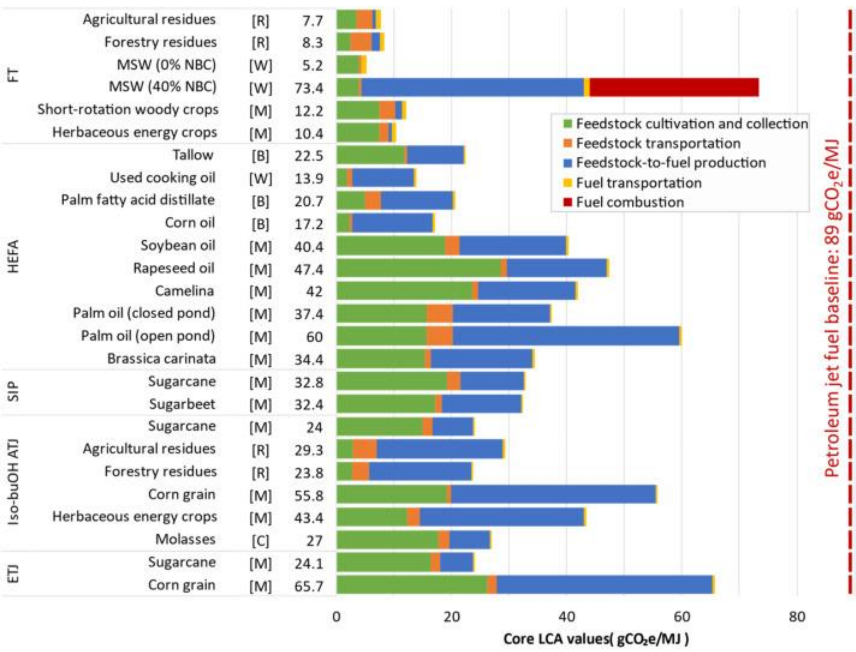

Figure 4: Default direct (referred as core) life-cycle assessment (LCA) values of SAF production pathways approved by ICAO. (NBC: non-biogenic carbon content). Source: Matteo Prussi, et al. *CORSIA: The first internationally adopted approach to calculate life-cycle GHG emissions for aviation fuels.*[46]

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[42] https://www.icao.int/environmental-protection/Documents/Assembly/Resolution_A41-21_Climate_change.pdf

[43] https://presidence-francaise.consilium.europa.eu/media/2hkh2v33/declaration-de-toulouse-pfue-ang_fr.pdf

[44] https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/

[45] https://www.destination2050.eu/

[46] https://www.sciencedirect.com/science/article/pii/S1364032121006833

The GHG intensity reduction benefits of SAF from biological origin compared to fossil-derived jet fuels are due to the CO_2eq compensation of biomass during its growth phase: in other words, CO_2 from fuel combustion is balanced by carbon uptake during photosynthesis, resulting in a corresponding credit of CO_2 emissions when the fuel is burnt[47]. This, however, requires that biomass grows as fast as it is burned for energy, otherwise there is a loss of carbon sinks and stocks that is equivalent to CO_2 emissions. For instance, the production of biofuels from food and feed feedstocks worldwide has led to direct and indirect land use change, such as deforestation, in several cases resulting in higher CO_2 emissions than conventional fossil fuels.

In the case of SAF of non-biological origin, the CO_2 from fuel combustion is balanced by carbon uptake directly from the atmosphere. For recycled carbon fuels the CO_2 is balanced by carbon that would otherwise be landfilled (if allowed), incinerated, or released to the environment.

The table below highlights the potentials of the current more mature technologies and according to the life-cycle values (LCA) reflected in the June 2022 edition of the ICAO's *CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels*.

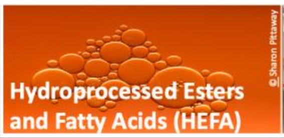
Sources: ICAO, Clean Skies for Tomorrow, SAF-TG	 Hydroprocessed Esters and Fatty Acids (HEFA)	 Fischer-Tropsch (FT)	 Alcohol-to-Jet (ATJ)	 Power-to-liquid (PtL)
Opportunity description	Safe, proven, and scalable technology	Significant potential in the mid-term, however, with techno-economic uncertainty		Proof of concept 2025+, primarily where cheap high-volume electricity is available
Technology maturity	Mature	Commercial pilot		In development
Feedstock	Waste and residue lipids, purposely grown oil energy plants. Transportable and with existing supply chains Potential to cover 5%-10% of total jet fuel demand	Agricultural and forestry residues, municipal solid waste, purposely grown cellulosic energy crops (e.g., poplar, miscanthus or switchgrass) High availability of cheap feedstock, but fragmented collection	Sugarcane, sugar beet, sawdust, lignocellulosic 2 Sustainable Aviation Fuel: Technical Certification residues (straw)	CO2 and green electricity Unlimited potential via direct air capture Point source capture as bridging technology
% LCA* GHG Reduction vs. fossil jet fuel	**14-100%*** *Due to soil carbon capture as per ICAO methodology	**76-100%*** *Due to soil carbon capture as per ICAO methodology	**76-100%*** *Due to soil carbon capture as per ICAO methodology	**12-100%*** *Due to soil carbon capture as per ICAO methodology

Table 2: Key SAF production pathways and CO_2 reductions potentials.

Benefits beyond CO_2

In addition to the reduction of CO_2 emissions, scientific evidence[48] shows that SAF has the additional benefit of reducing air pollutant emissions around airports, as it emits up to 90%

[47] CORSIA: The first internationally adopted approach to calculate life-cycle GHG emissions for aviation fuels, https://www.sciencedirect.com/science/article/pii/S1364032121006833

48 https://www.mdpi.com/1996-1073/14/7/1858; https://pubs.acs.org/doi/10.1021/acs.est.1c04744

less non-volatile Particulate Matter (nvPM) and up to 100% less sulphur (SO_X), compared to fossil jet fuel[49].

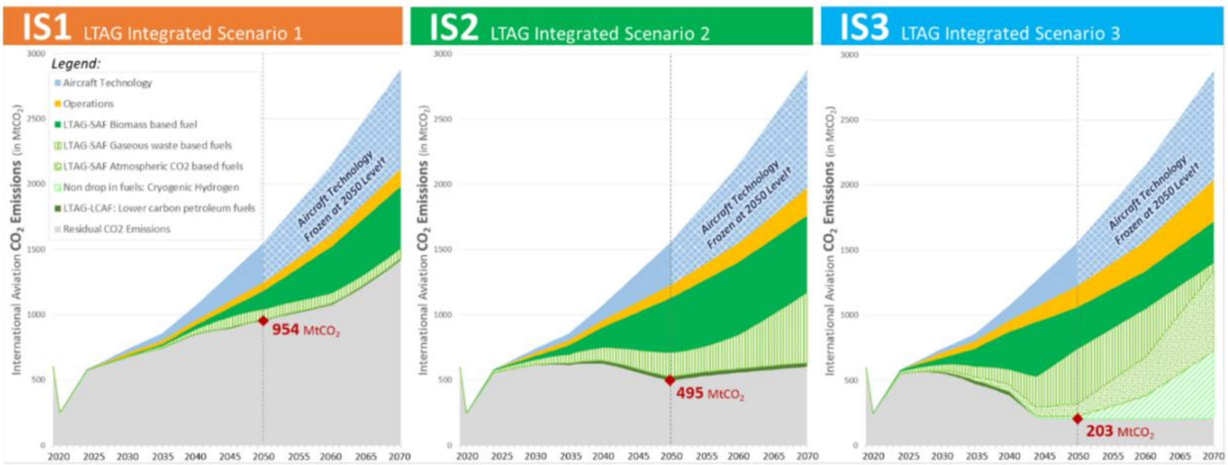
Due to such reduced non-CO_2 emissions, SAF could also decrease aviation's warming effect on the climate (radiative forcing), which is historically at least as important from non-CO_2 as from CO_2. Further scientific research suggests that SAF can produce 50%-70% fewer soot particles, which could reduce the warming impact of contrails[50].

Large-scale SAF use can therefore potentially provide important supplemental benefits. Several European projects[51] are exploring these benefits and EASA published in 2020 an *updated analysis of the non-CO_2 climate impacts of aviation* which identifies contrail prevention as having a potential key role in curbing global warming.

Since the beginning of 2021, EUROCONTROL's[52] Maastricht Upper Area Control Centre (MUAC), in partnership with the German Aerospace Center (DLR), have been conducting a first worldwide live ATM operational trial on contrail prevention aimed at mitigating the climate impacts of non-CO_2 emissions[53].

The ICAO global Long-Term Aspirational Goal (LTAG)

The ICAO 41st Assembly adoption in October 2022 of a LTAG for international aviation of net-zero carbon emissions by 2050 was based on an analysis made by the ICAO Committee for Aviation and Environmental Protection (CAEP) reflected in a *Report on the Feasibility of a Long-Term Aspirational Goal* (LTAG)[54], issued in March 2022.



† Caution required with the interpretation of absolute CO_2 emissions levels after 2050 due to modelling assumptions e.g., frozen aircraft technology after 2050. Under these assumptions, CO_2 emissions are higher than in an alternative scenario (and modelling approach) where aircraft technology would continue to improve after 2050.

Figure 5: CO_2 emissions associated with LTAG Integrated Scenarios

49 ICAO 2016 Environmental Report, Chapter 4, Page 162, Figure 4.

50 https://www.nasa.gov/press-release/nasa-dlr-study-finds-sustainable-aviation-fuel-can-reduce-contrails

51 https://www.acacia-project.eu/; https://www.alternateproject.com/

52 See Glossary

53 https://www.eurocontrol.int/press-release/mitigating-climate-impact-non-co2-emissions

54 https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx

Three integrated scenarios were developed for the LTAG analysis to cover a range from lower to higher aspirations. All of them noticeably identify that *drop-in fuels have the largest impact on residual CO_2 emissions, driving the overall reductions by 2050*.

The report also notes that the costs and investments associated with the scenarios are largely driven by fuels (e.g. SAF) acknowledging that incremental costs of fuels (i.e. minimum selling price of SAF compared to conventional jet fuels) further motivates fuel (energy) efficiency improvements from aircraft technology and operations. This will also require investments from governments and industry.

As an illustrative quantified example, in the most ambitious scenario IS3, in 2050, more aligned than the others with the final Assembly decision of aspiring to reach Net Zero CO_2 emissions[55] by 2050, SAF would supply 96% of international jet fuel demand, achieving an 81% reduction of CO_2 emissions. Such a scenario represents a policy landscape with a strong emphasis on SAF promotion worldwide. In this scenario, emissions in 2050 would be reduced by 87% from the baseline scenario broken down into 21% from aircraft technologies, 11% from operations and 55% from fuels.

Some of the current pathways eligible under CORSIA, while necessary in the short-term, would not deliver sufficient CO_2 savings by 2050. The role of SAF of non-biological origin (such as PtL) is key to achieve this ambition level together with the possibility of higher-blend grades compared to today's grades certified by ASTM.

Volumes													
		F1				**F2**				**F3**			
Year		**Global**	**Share**	**Intl**	**LCA**	**Global**	**Share**	**Intl**	**LCA**	**Global**	**Share**	**Intl**	**LCA**
	Units	kt/year	%	kt/year	gCO_{2e}/MJ	kt/year	%	kt/year	gCO_{2e}/MJ	kt/year	%	kt/year	gCO_{2e}/MJ
2035	**Demand**	**396399**	**100%**	**244999**	**85.0**	**391184**	**100%**	**241819**	**71.5**	**380753**	**100%**	**235459**	**56.3**
	SAF-FTG	10208	2.6%	6309	29.0	50113	12.8%	30978	26.4	96881	25.4%	59912	24.2
	SAF-CO_2	10208	2.6%	6309	17.6	43049	11.0%	26612	16.7	49736	13.1%	30757	16.1
	SAF-DAC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17495	4.6%	10819	12.2
	LCAF	29076	7.3%	17971	80.1	67907	17.4%	41978	80.1	137779	36.2%	85203	80.1
	SAF+LCAF	**49492**	**12.5%**	**30589**	**56.7**	**161069**	**41.2%**	**99568**	**46.44**	**301890**	**79.3%**	**186690**	**47.7**
	LH2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0.0%	0	8.6
	Jet A/A-1	346907	87.5%	214410	89.0	230115	58.8%	142251	89.0	78863	20.7%	48769	89.0
2050	**Demand**	**606829**	**100%**	**375459**	**71.6**	**576830**	**100%**	**357319**	**39.0**	**542948**	**100%**	**335619**	**16.8**
	SAF-FTG	112523	18.5%	69620	30.9	305031	52.9%	188952	26.6	222599	41.0%	140324	24.7
	SAF-CO_2	51200	8.4%	31679	18.3	109480	19.0%	67818	12.9	244593	45.0%	154188	12.5
	SAF-DAC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	54924	10.1%	34623	8.4
	LCAF	45343	7.5%	28055	80.1	162319	28.1%	100549	80.1	0	0.0%	0	80.1
	SAF+LCAF	**209066**	**34.5%**	**129354**	**38.5**	**576830**	**100%**	**357319**	**39.0**	**522116**	**96%**	**329135**	**17.3**
	LH2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20832	3.8%	6485	5.6
	Jet A/A-1	397763	65.5%	246105	89.0	0	0.0%	0.00	89.0	0	0.0%	0	89.0

Table 3: ICAO CAEP's projected fuel needed to meet 100% of expected LTAG Scenarios' fuel demand and corresponding LCA values for fuel categories considered, and the overall mix.

Global: International and domestic fuel burn demand
Share: Percent of total demand per fuel category
Intl: International only share of global fuel burn demand
LCA: lifecycle values given in units of gCO2e/MJ
SAF-FTG: LTAG-SAF from biomass and solid/liquid waste
SAF-CO2: LTAG-SAF from waste CO2
SAF-DAC: LTAG-SAF from atmospheric CO2
LH2: shown are volumes of Jet A/A-1 displaced by hydrogen demand, these volumes do not represent liquid hydrogen volumes
LCAF: Lower Carbon Aviation Fuels as defined in ICAO CORSIA

[55] See Glossry

To provide further examples of how emissions goals can be converted into SAF supply goals, the table above, extracted from *the ICAO Report on the Feasibility of a Long-Term Aspirational Goal* (Appendix M5, Table 4.6), provides quantified volumetric results (in kt per year) needed to meet 100% of expected fuel demand under an intermediate traffic forecast in 2035 and 2050. The table includes a breakdown of global and international volumes for each fuel category considered in the study (detailed in notes below the table) along with its respective estimated life-cycle GHG emissions (LCA) values for each fuel category and for the overall fuel mix.

1.4.2. SAF as a means to reduce energy and fossil fuel dependency

In addition to tackling the climate crisis, the energy supply chain disruption caused by the Russian Federation's invasion of Ukraine in 2022 has heightened energy security concerns and highlighted the role of renewable energy sources, including SAF, as contributing to transforming the European energy system and reducing its energy dependency.

The REPowerEU Plan presented by the European Commission in May 2022 aims to end the EU's dependence on fossil fuels, in addition to addressing climate change, through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy to replace fossil fuels. The Recovery and Resilience Facility (RRF), designed to counter the economic and social impacts of the Covid-19 pandemic, is at the heart of the REPowerEU Plan, supporting coordinated planning and financing of cross-border and national infrastructure as well as energy projects and reforms.

The impact assessment for the ReFuelEU Aviation's proposal underlined that the net reduction in energy imports in the EU resulting from its implementation would be substantial, driven by a significant drop in imports of crude oil products, and in spite of a small increase in biofuel imports. Oil imports would be largely substituted with renewable feedstocks and renewable electricity primarily sourced in the EU.

1.4.3. The European aviation sector climate roadmaps

In February 2021 Europe's aviation sector launched its flagship sustainability initiative, Destination 2050 – A route to net zero European aviation[56]. It is driven by a report which provides a vision and path for meaningful CO_2 emission reduction efforts in Europe and globally. Building on the Paris Agreement and the European Green Deal, it includes in its scope all flights within and departing the EU, UK and EFTA projecting net zero CO_2 emissions by 2050 completing in-sector reductions with out-of-sector economic measures to offset remaining emissions.

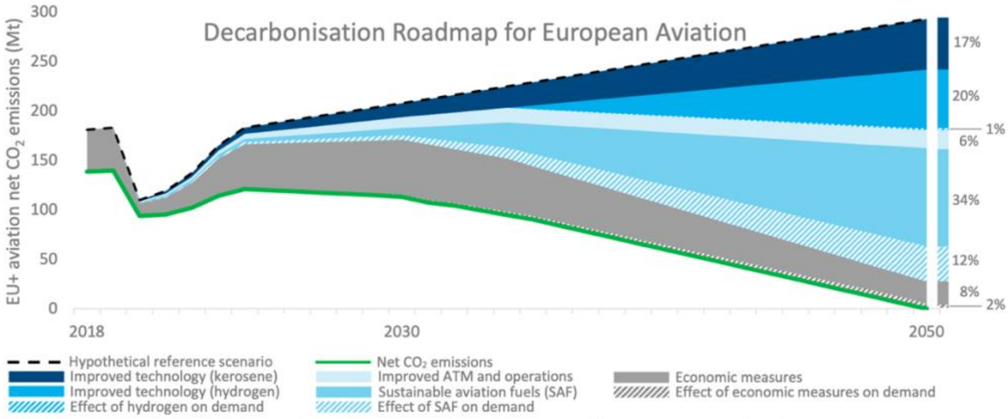
It was followed by the global air transport industry's long-term climate goal Commitment to Fly Net-Zero[57] carbon emissions by 2050, confirming the commitment of the world's airlines,

56 https://www.destination2050.eu/

57 https://aviationbenefits.org/FlyNetZero

airports, air traffic management and the makers of aircraft and engines to reduce CO_2 emissions in support of the Paris Agreement 1.5ºC goal.

Sustainable aviation fuels are key elements of these industry strategies as they have the potential to significantly reduce aircraft life cycle CO_2 emissions, if produced according to robust sustainability standards.



Results are presented for all flights within and departing from the EU region[2]. Improving aircraft and engine technology, ATM and aircraft operations, SAF and economic measures all hold decarbonisation potential. Modelled for 2030 and 2050, the impacts are linearly interpolated. The base year for this study is 2018.

Figure 6: Decarbonisation roadmap for European aviation (Source: Destination 2050)

Destination 2050 foresees that SAF delivers a major contribution to achieving net zero carbon emissions in 2050. The supply of SAF may increase from 3 Mt in 2030 to 32 Mt in 2050, equal to 83% of the total kerosene consumption. The SAF contribution is directly linked to the development of industrial production capacity and strongly influenced by a supporting long-term policy framework.

In addition, in July 2022, the UK government published their Jet Zero Strategy which focuses on the rapid development of technologies in a way that maintains the benefits of air travel whilst maximising the opportunities that decarbonisation can bring to the UK. This strategy builds on the commitments and progress made in the Net Zero Strategy, Transport Decarbonisation Plan and Flightpath to the Future and sets out the government's overall strategic approach for decarbonising the sector.

Some of the key jet zero policies include:

- A commitment to have a SAF mandate in place by 2025 and to a target of at least 10% SAF in the UK jet fuel mix by 2030;
- A CO_2 emissions reduction trajectory that sees UK aviation emissions peak in 2019;
- A target for English airports to reach zero emission by 2040; and
- A target for UK domestic flights to reach net zero by 2040.

The nascent nature of these technologies means that the optimal technological mix for achieving Jet Zero is not yet known. Therefore, the UK government has committed to reviewing the strategy every five years to monitor the UK's emissions reduction pathway. This means they will have capacity to adapt their approach if necessary.

2. SAF barriers and the need for regulatory and policy action

As shown in the previous Chapter, industry and governments globally expect SAF to play a fundamental role in the decarbonisation of the aviation sector by 2050, in conjunction with other in-sector measures such as zero-carbon aircraft. While the latter is expected to take a more important role beyond 2050, SAF can also drive industrial opportunities and economic growth, as further analysed in Chapter 4.

ECAC States share the aspiration of achieving net-zero CO_2 emissions by 2050, in line with the temperature goals of the Paris Agreement. For that, strong support for SAF in national, regional and international policies is needed and achieving this ambition requires overcoming important barriers.

The challenges listed below have been identified in the CST SAF Policy Toolkit and through SAF-TG consultation with European stakeholders.

2.1. Major identified challenges to upscaling SAF

Cost differential

Currently, the largest barrier to wider SAF use is cost. SAF production expenses result in market prices 2-6 times greater than traditional fossil jet fuel, depending on the production pathway used, limiting the potential for market-driven scale-up. In the EU, this price differential has decreased already due to the cost of carbon in the Emissions Trading System (EU ETS)[58], where SAF is zero-rated. However, further regulation and economic incentives will be required to help bridge this cost differential, drive demand, and generate greater predictability for investors and financiers.

Marginal abatement cost

Cost differential is definitely one of the most significant barriers for SAF deployment. Given the value of the CO_2 saved by using a SAF, a relevant parameter is the marginal abatement cost potential (which measures the cost of reducing each additional unit of CO_2): the ratio between the two above mentioned parameters allows for determining the CO_2 marginal abatement cost (EUR/tonne of CO_2 saved). This is a key parameter for choosing to support a technological option in favour of others. Potential figures for this marginal abatement cost for various technologies are provided under the scenario IS2 of the ICAO CAEP Report on the Feasibility of a Long-Term Aspirational Goal (LTAG).

Technological readiness

Theoretically, there is sufficient feedstock globally to power all of aviation with SAF by 2030; however, it is necessary to make improvements in feedstock production and collection and in technology allowing for the use of a broader range of feedstock types. New scalable production routes include alcohol-to-jet (AtJ), gasification/Fischer-Tropsch (G/FT), and power-to-liquid (PtL). Critical investments in research, development and demonstration

58 See Glossary

(RD&D) are needed to see these technologies and production pathways mature and reach a meaningful scale of industrial production.

Sectoral distribution

Aviation is not the only transport sector that must decarbonise but it is one of the more difficult to abate. Currently, the road sector uses the majority of renewable fuels. Higher production costs associated with SAF output and more limited demand uptake are disincentives for producers to redirect feedstock to aviation where no mandatory targets are currently enacted (to address this challenge some ECAC States have already established mandatory targets, and the EU and others are in the process). In many states there is often little inter-sectoral coordination, which compounds the challenge.

Investment

As highlighted in the ICAO Report on the Feasibility of a Long-Term Aspirational Goal (LTAG), the transition to SAF requires major investments. To start to scale the production capacity for fuels under the LTAG more ambitious scenario, investments would need be of around USD 3 200 000 million, broken down into USD 950 000 million for SAF biomass-based fuels by 2050 (to cover 42% of international aviation energy use in 2050), USD 1 700 000 million for SAF from gaseous waste (46%), and USD 460,000 million from SAF from atmospheric CO_2 (10%). It may be necessary to build or remodel entire processing facilities and develop entire supply chains. Other studies expect investments to bring global aviation to net zero by 2050 to be of about USD 175,000 million n upfront capital annually on average until 2050[59]. The ReFuelEU Aviation initiative Impact Assessment estimated that by 2050, a total of 104-106 additional SAF production plants are needed across the EU to satisfy the SAF supply obligation corresponding to an increase in production capacity of around 25.5-25.6 million tonnes of SAF per year.

This could also be seen as an opportunity, at European level, for attracting investors, generating new jobs and for the fuel suppliers to keep a market that would otherwise diminish due to the progressive electrification of other transportation modes. Clear and stable SAF targets could provide sufficient predictability of future demand, helping to de-risk the first wave of projects.

Level playing field

It is essential to ensure a level playing field across the air transport markets when it comes to the use of aviation fuel. Indeed, aviation fuel accounts for a substantial share of aircraft operators' costs, i.e. up to 25% of operational costs[60]. Variations in the price of aviation fuel can thus have important impacts on aircraft operators' economic performance.

In the absence of a global mandate or agreed decarbonisation pathway, progress is most likely at the national or regional level with limited global coordinated efforts. Such an approach is of concern for industry, as implementation that is limited in scope is likely expected to result

59 Energy Transitions Commission, Making Net-Zero Aviation Possible, July 2022

60 Explanatory Memorandum to COM(2021)561 - Ensuring a level playing field for sustainable air transport.

in inefficiencies and reduced overall effectiveness due to issues like competitive distortion or carbon leakage (where aviation markets or hubs would move from a country with stringent policies, to a country that is more lenient, leading to an increase in greenhouse gas emissions..

Differences in the price of aviation fuel between geographic locations, can lead aircraft operators to adapt their refuelling strategies for economic reasons. *Tankering* -see Glossary- occurs when aircraft operators uplift more aviation fuel than necessary at a given airport, with the aim to avoid refuelling partially or fully at a destination airport where aviation fuel is more expensive.[61] Fuel tankering leads to higher fuel burn than necessary, hence higher emissions, and undermines fair competition in the air transport markets. To avoid this, the ReFuelEU Aviation legislative proposal has established specific anti-tankering provisions (see Chapter 3.1 below).

SAF reporting and claiming under different jurisdictions and scopes

As the supply and demand of SAF is increasing driven by State and regional policies and by a growing number of companies seeking to tackle their aviation-related indirect (so-called Scope 3)[62] emissions incurred from their employees' travel or freight, SAF reporting and claiming under different jurisdictions and scopes within Europe could face practical challenges.

One such challenge is that under some European jurisdictions, which are based on regulations designed for road transport, the proof of sustainability issued by the certification scheme is not given to the end user (aircraft operator) as it needs to be delivered by the fuel provider to national authorities to certify that the blended SAF meets the sustainability criteria required when complying with national mandates. The airlines also need such proof to demonstrate the compliance of the fuels with the sustainability criteria required, in order to claim the SAF use benefits (e.g. under Emission Trading Systems - ETS - or CORSIA), but the Proof of Sustainability (PoS) cannot be issued more than once.[63] In addition, as corporations and other organisations wish to support aviation's net-zero pathway, while also achieving their own direct and business-travel emissions reduction targets, they wish to claim under voluntary scopes the CO_2 reductions achieved from SAF use. Mechanisms to achieve both regulatory and voluntary ambitions are needed.

The Clean Skies for Tomorrow (CST) initiative has developed a SAF certificate (SAFc) framework, including recently released emissions accounting and reporting guidelines for voluntary SAF transactions covering both scope 1 and 3 emissions [64], which partially addresses this need.

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[61] https://www.eurocontrol.int/sites/default/files/2020-01/eurocontrol-think-paper-1-fuel-tankering.pdf

[62] The *GHG Protocol Corporate Standard* classifies a company's GHG emissions into three 'scopes'. Scope 1 emissions are direct emissions from owned or controlled sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.

[63] However, this is under consideration while developing the Union Database (UDB), that will be a register for all certified biofuels, bioliquids and biogas that count towards EU targets for renewable energy.

[64] https://www.weforum.org/whitepapers/sustainable-aviation-fuel-certificate-safc-emissions-accounting-and-reporting-guidelines

The tables below showcase some of those requirements under different jurisdictions. It should be noted that this information is illustrative only and does not attempt to be an exhaustive compilation of all applicable regulatory requirements.

Scheme	EU RED	ReFuelEU	EU ETS	CORSIA	[65]SBTi
ISCC Plus					
RSB					
ISCC EU					
RSB EU RED					
ISCC CORSIA					
RSB CORSIA					
Nat. Sust. Schemes*	* National Sustainability Schemes not recognised by the EC for RED certificates are not valid outside the State & limit exports/imports				

Table 4: Examples of compatibility of Sustainability Certification Schemes

Feedstock/ programme		EU RED	ReFuelEU	EU ETS	UK SAF mandate	CORSIA
GHG savings threshold		Bio 65% RCF & PTL 70%	Bio 65% RCF & PTL 70%	Bio 65%	50%	10% (ILUC included)
Fossil comparator (gCO2e/MJ)		94	94	94	89	89
BIO	**High ILUC (indirect land-use change)**	Phase out 2030				
	Food & Feed crops	Capped max 7%				
	Low ILUC (indirect land-use change)		*			Can benefit from negative ILUC
	RED Annex IX.A	Sub-target				
	RED Annex IX.B	Capped				
NON BIO	**PTL (Power to Liquid)**	Sub-target	Sub-target	*		
	RCF (Recycled Carbon Fuels)	Up to MS	*	*		
	LCF (Low Carbon Fuels)	*	*			
	LCAF (Lower carbon Aviation Fuels) -See Glossary-					

Non eligible	Eligible	Eligible capped	Eligible limited

* provision for inclusion under discussion.

Table 5: Examples of regulations compatibility – types of SAF according to groups of feedstocks

65 Science Based Targets initiative: https://sciencebasedtargets.org

Table 6 shows current in force regulations and possible approaches for the regulations under legislative process (ReFuelEU and UK SAF mandate)

Scheme	Scope	Methodology	Units
RED II	Fuel supplier & State	LCA, energy based, no ILUC [ref 94]	CO_2e/MJ, multipliers
ETS	Aircraft operator	Biomass fraction	tonnes (t) (reporting NCV)
ReFuelEU Aviation	Fuel supplier	SAF fraction	tonnes (t) [+CO_2e/MJ]
UK SAF mandate	Fuel supplier	LCA, energy based, no ILUC [ref 89]	CO_2e/MJ
CORSIA	Aircraft operator	LCA, ILUC [ref 89]	CO_2e/MJ [+tonnes]
SBTi	Scope 3	LCA, ILUC [ref 89]	CO_2e/MJ [+tonnes]

Table 6: Illustrative examples of different scopes, methodologies and metrics used

SAF Logistics and traceability

Government established mandates on minimum SAF content in aviation fuel supply can follow different approaches or a combination of approaches affecting SAF logistics.In all cases ensuring the fulfilment of sustainability requirements in the whole value-chain is fundamental to ensure the delivery of emissions reductions.

Options can include:

- Obligation of physical delivery of SAF in every airport supply.
- Mass-balance systems, which are records that ensure traceability of biomass quantities at all levels of production and distribution of the SAF.
- Book and Claim, which is a chain of custody system that de-couples specific SAF attributes, like its environmental benefits, from the physical product and transfers them separately. These mechanisms enable airlines to purchase and claim SAF attributes in one location, while the physical SAF delivery and use occurs elsewhere, usually closer to the production location.

The regulatory mandates can be designed with some flexibility mechanisms, especially until the SAF markets are sufficiently mature, as delivering SAF on every single flight departing from a jurisdiction with a mandate may be challenging. The mixing/blending of SAF may happen at the refineries, or at ad hoc blending facilities, or at the entry point in the supply infrastructure network. The verification, monitoring and reporting may happen either throughout all the value chain or at the blending point. Then the airport receives already blended fuel and distributes to all airlines without having to demonstrate anything else at tank level.

In addition, introducing SAF at large scale in airports implies infrastructure and operational challenges. As referred in Chapter 1.2 dedicated to SAF Qualification, SAF are considered a drop-in solution. However, in its pure form, work still needs to be done to make it fully compatible with existing distribution systems, storage infrastructure and aircraft. This means that the future SAF supply chain needs logistics and blending facilities for SAF that can scale to the hundreds of millions of tonnes required.

The study *Integration of Sustainable Aviation Fuels into the air transport system*[66], produced by ACI World and the Aerospace Technology Institute (ATI), provides an overview of the infrastructure and operational requirements of introducing sustainable hydrocarbon fuels at airports. It addresses the practical challenges and solutions to deploy SAF, from one-off flights to fully integrated supply chains.

SAF meeting sustainability criteria under different regulatory regimes

An additional challenge is that the SAF supplied might need to comply with different sets of sustainability criteria under different regulatory regimes (e.g. EU Renewable Energy Directive -RED- and CORSIA) which is a barrier for airlines as it adds complexity. Voluntary certification schemes are working towards combining requirements to reduce the burden.

The obligation to comply with different sustainability criteria, not only in relation to the types of feedstocks permitted, but also on the emissions reduction values to be considered for SAF, could create challenges for industry when flying and reporting across regions. In addition, setting insufficient CO_2 reduction requirements would endanger the ability to reach the net zero carbon emissions goal by 2050 for international aviation.

Greenwashing

In addition to the development and use of robust sustainability criteria for SAF, it is of extreme importance that any action towards decarbonisation of the aviation sector is genuine and communicated truthfully. Misleading claims of carbon neutral or zero-emissions flights that lead to legal actions undermine genuine initiatives.

2.2. The need for policy intervention

Most countries have adopted some form of renewable energy policy at the national level, scaling industry's development, investment, and environmental benefits in recent years. In particular, public policy has played a pivotal role in scaling renewable energy markets such as wind and solar electricity and developing biofuels for road transport[67]. Additional policy-support is now needed for SAF.

[66] https://store.aci.aero/product/aci-ati-integration-of-sustainable-aviation-fuels-into-the-air-transport-system/

[67] International Renewable Energy Agency (IRENA), International Energy Agency (IEA) and REN21, Renewable Energy Policies in a Time of Transition, April 2018.

Accelerating the pace of aviation decarbonisation will require a coherent set of policy interventions that rapidly strengthen the business case for private investment, bridging the price differential with conventional fossil jet fuel, progressively contributing to lowering production costs and stimulating SAF demand. Failure to achieve this will be detrimental for society and the entire aviation value chain as slower emissions reductions today will necessitate a steeper and overall higher cost of transition in the future.

Five key areas where policy interventions can have the most impact were identified in the CST Policy Toolkit and are referred to in Chapter 5 of this document.

Domestic and international policies are both necessary

A joint global SAF supply objective and international consensus through ICAO on a global framework for SAF deployment in a sustainable manner, would be optimal to increase their uptake. Capacity-building (such as the ECAC capacity-building for Environment and the ICAO ACT-SAF programme) and climate financing would also be fundamental tools, particularly as States vary in their political and technological readiness to create and participate in SAF markets.

Importantly, domestic, and international aviation often fall under different jurisdictions. Domestic aviation normally comes under national laws, while the International Civil Aviation Organization (ICAO) oversees international aviation. Even with a robust international system in place, a coherent national and regional policy aligned with, and steering, initiatives at the international scale will play an important role in developing the SAF market[68].

The broader value chain is also a significant contextual component. National and regional policy will be required to incentivise the production of sustainable bio and non-bio feedstocks, build up national supply chains, and ensure that enough sustainable feedstock is allocated to SAF production.

The value of regional and global harmonisation

Wherever possible, national and regional policies should seek to align with and steer international sustainability standards. This will support both the longer-term goal of a robust international SAF market and will also facilitate efficient international aviation and trade and effective emissions accounting in the short term.

A lack of policy and regulatory harmonisation risks leading to a patchwork of systems and requirements that results in carbon leakage, missed technological and feedstock opportunities, and underinvestment due to concerns about market stability.

Harmonisation by ECAC States and beyond could tackle some of the challenges identified above in this chapter. This guidance includes recommendations in its Section III, developed with that aim.

68 IRENA, Reaching Zero with Renewables: Biojet fuels, IEA, 2021.

3. The European SAF policy landscape

3.1. The EU Green Deal and the ReFuelEU Aviation initiative

The European Commission presented in July 2021 the ReFuelEU Aviation proposal, aimed at boosting the supply and demand for SAF in the EU, through a blending obligation on fuel suppliers to EU airports[69]. The obligation would commence from 2025 at 2% blending of SAF, gradually increasing to 63% in 2050. The proposal also includes a sub-obligation of 0.7% blending for *synthetic fuels*[70] from 2030, gradually increasing to 28% in 2050. To avoid fuel tankering, an obligation is also placed on aircraft operators[71] to uplift fuel from EU airports. This proposal is undergoing the EU legislative process.

The proposed Regulation is of relevance to the European Economic Area (EEA). Once the new Regulation is adopted, it will be applicable in the EU Member States, and once incorporated into the European Economic Area Agreement also in Iceland, Liechtenstein and Norway. Furthermore, it is the intention of the European Commission to extend its application to other partner countries in the EU's neighbourhood in the framework of the comprehensive air transport agreements which they signed with the EU.

The European Commission also launched in 2022 a Renewable and Low-Carbon Fuels Value Chain Industrial Alliance. This is a new initiative that focuses on boosting production and supply of renewable and low-carbon fuels in the aviation and waterborne sectors in the EU. It is a key flanking measure to the RefuelEU Aviation and FuelEU Maritime initiatives.

In 2012, aviation was brought into the EU's Emissions Trading System (EU ETS). Since then, SAF used and reported, meeting the EU RED criteria, is enjoying the incentive of being zero-rated under the EU ETS.

3.2. European States' policies

Several European States have established national policy actions to promote the supply and use of Sustainable Aviation Fuels (SAF). A summary of those policy initiatives is included below.

It should be noted that some of the national initiatives from EU States (identified by an *) summarised below, were developed before the EU proposal under the ReFuelEU Aviation initiative, which introduces a Union harmonised approach to supply and uplift of SAF.

69 Airports where passenger traffic was higher than 1 million passengers or where the freight traffic was higher than 100,000 tons in the reporting period, and are not situated in an outermost region.

70 In the regulatory proposal (COM(2021) 561 final, Page 135) Synthetic fuels are defined as "sustainable aviation fuels based on non-biologic origin (RFNBOs), where the source of energy is not based on crops, or residues or waste, but obtained from renewable electricity" as per the definition of RFNBOs, referred in Article 2, second paragraph, point 36 of Directive (EU) 2018/2001.

71 Who performed at least 729 commercial air transport flights departing from Union airports in the reporting period (as per the proposal presented in July 2021).

*Denmark**

The Danish government has set an ambition to make it possible to establish one green aviation domestic route by 2025. By 2030, all domestic aviation in Denmark should be green. The private sector and universities are working to develop greener technologies and fuels for planes.

Moreover, the Danish government has introduced a Strategy for Power-to-X, which aims to boost indirect electrification in hard-to-abate sectors. In addition, Denmark has earmarked DKK 1.25 billion to support the production of green hydrogen, as well as other support schemes to increase the industrialisation of green hydrogen. Among other things, Denmark is looking into the possibility of lower tariffs for major electricity consumers such as hydrogen producers, and taking the first steps towards a national hydrogen infrastructure.

In 2019, the government introduced a climate partnership with the aviation sector, among other sectors, tasked with presenting a proposal on how the sector could contribute to greenhouse gas reductions in a just way, supporting Danish competitiveness, exports, jobs, welfare and prosperity. The aviation sector proposed an aviation climate fund to subsidise SAF to make it competitive with conventional jet fuels. The proposal would, according to the climate partnership, lead to a minimum of 70% greenhouse gas reductions on domestic air travel by 2030 compared to 1990 levels, and a minimum of 30% greenhouse gas reductions on international air travel by 2030 compared to 2017.

*Finland**

The Finnnish government's programme *"Inclusive and competent Finland"* aims to reduce aviation emissions by introducing a blending obligation for sustainable aviation fuels, with a target of 30% renewables by 2030. In this context, an impact assessment report presenting a variety of distribution obligation implementation paths to reduce air traffic emissions was published in December 2020.

*France**

The French government established at the end of 2019 its "*French roadmap for the deployment of sustainable aeronautical biofuels*" which sets a SAF blending trajectory of 1% in 2022, 2% in 2025, 5% in 2030 and 50% in 2050.

To further establish this roadmap, the French government started with the launch of a Green Growth Commitment[72] in 2017 focusing on SAF to gather adequate information. This public-private partnership gathered some of the main stakeholders of the SAF supply-chain and was tasked to identify the required conditions to sustain the development of a SAF production sector in France. To complete this preliminary work, a call for expression of interest was launched in 2020 to identify the type of SAF production projects stakeholders would be interested in carrying out, as well as scale-up needs. Such work allows the French government

[72] https://www.ecologie.gouv.fr/sites/default/files/ECV%20-%20Mise%20en%20place%20d%27une%20fili%C3%A8re%20de%20biocarburants%20a%C3%A9ronautiques%20en%20France.pdf

to identify the type and adequate level of support to be implemented in order to meet the roadmap objectives: a call for projects for the development of a French production sector for SAF[73] was launched between July 2021 and September 2022. Several projects should be awarded (analysis still on-going).

To support the consumption of SAF at the national level, a SAF annual blending mandate, of 1% has been created in 2020 and started in 2022. It will undergo an annual revision to ensure its alignment with the French SAF roadmap, and later on its alignment with any EU regulation (see above).

Germany*

The 2019 German government's Climate Action Program 2030 sets programmes and measures for R&D funding as well as financial support for the market uptake of carbon-neutral e-fuels for aviation. In the national implementation of the EU-Renewable-Energy-Directive (REDII), Germany agreed to a blending quota for PtL (Power to Liquid)-kerosene starting from 2026 with a quota of 0.5% PtL-kerosene, 1% in 2028 and 2% in 2030 of kerosene volumes sold in Germany, while at the same time addressing market distortion. The National Hydrogen Strategy and its implementation reiterates among others the support of hydrogen derivatives such as PtL for aviation.
The Federal Government, the German states, the aviation industry, the petroleum industry as well as plant manufacturers and operators developed in 2021 the *PtL Roadmap for Aviation*: a joint roadmap for the market ramp-up of sustainable aviation fuels from renewable energy sources.

Netherlands*

With the national implementation of the Renewable Energy Directive II it became possible for aviation to voluntary contribute to the transport goal under the RED II, the so called 'opt-in', until 1 january 2025. A multiplier was introduced on a national level to stimulate the use in aviation (and maritime). It serves as a transitional policy until an aviation specific blending obligation is introduced.

In March 2020, the Dutch government announced the introduction of a Sustainable Aviation Fuels (SAF) blending obligation by 2023, if a European obligation or plans to implement one is not put in place by this time. This announcement was made on the basis of a "*Study on the potential effectiveness of a renewable energy obligation for aviation in the Netherlands*" carried out for the Dutch government in 2019. In May 2020, the Dutch government published the policy framework *'Responsible flying towards 2050 - Draft Aviation Memorandum 2020-2050'* in which the goal is set that 14% of all aviation fuel uplifted in the Netherlands has to be sustainable by 2030 and increasing to 100% by 2050.

[73] https://agirpourlatransition.ademe.fr/entreprises/aides-financieres/20220503/appel-a-projets-developpement-dune-filiere-production-francaise

Norway

The Norwegian government established a blending obligation to aviation fuel suppliers for a 0.5% minimum content of advanced biofuel from 1 January 2020. The Norwegian government has stipulated that the biomass to produce it should come from wastes and residues. The fossil-free aviation roadmap was established as a goal in Norwegian aviation's sustainability report in 2020. A dedicated SAF roadmap was then published in 2021.

*Poland**

In 2019, the Polish government established the *National Energy and Climate Plan for the years 2021-2030* and proposed 14% of renewable energy sources in transport by 2030. In 2021, the *Polish Hydrogen Strategy by 2030 with a perspective until 2040* was published. The document assumes national industry initiatives in the pilot phase before 2025 and further increase of the use of hydrogen in air transport before 2030.

In 2021, the Polish government ran also a public consultation on the *Civil Aviation Development Policy by 2030 with a perspective until 2040*. The document confirms that the reduction of the negative impact on the environment should be one of the priorities for airports and air carriers in Poland and the aviation sector should make a significant contribution to the reduction of global CO_2 emissions. Whereas by 2035 SAF will have the growing role, the document requires that some actions be implemented in Poland. One of them is creating conditions for the efficient use of SAF at Polish airports, including the creation of an appropriate infrastructure enabling the use of SAF. The document is currently in the final consultation phase and is planned to be published in 2023.

*Spain**

In 2019, the Spanish government proposed two legislative frameworks which included a SAF obligation to aviation fuel suppliers. Firstly, the *Spanish 2021-2030 Integrated Plan for Energy and Climate* submitted to the EU in 2019, which recognises the relevance of SAF, in particular the development of advanced biofuels. Secondly, the *Spanish Climate Change Law,* approved in 2021, which enables the government to establish annual renewable energy targets specific for the aviation sector, with special focus on advanced biofuels and renewable fuels of non-biological origin.

A public-private value-chain platform (Bioqueroseno) was created in 2011 as a means to stimulate cooperation of stakeholders thorough the complete value in setting a SAF roadmap and to enhance deployment and R&D (leading to a project such as ITAKA). The use and update of the former website has been discontinued, but still contains some useful references. The Spanish Centres of Excellence, promoted by the Civil Aviation Authority (AESA), also have a section devoted to defining the key actions for SAF deployment as a central element of aviation decarbonisation.

In addition, a Green Hydrogen for Aviation Alliance has been created, uniting government, airports, airlines, OEMs and aviation fuel and hydrogen producers and logistics, with a specific working group to foster and promote the production and uptake of e-fuels, proposing roadmaps, working *fora* and helping potential projects to access the supporting mechanisms.

*Sweden**

The Swedish government has established a regulation for GHG emissions reduction obligation for jet fuel suppliers to promote the use of SAF, which came into force on 1st August 2021 and stretches until the end of 2030 with decreasing GHG intensity of fuels each year. SAF blend ratios will be needed to meet the reduction obligation, increasing approximately from 1% by volume in 2021 to 30% in 2030.

There is a national industry roadmap for fossil free aviation, including both SAF and electric aviation, under the Fossil Free Sweden initiative of the Swedish government.

Switzerland

In its long-term climate strategy, the Swiss Federal Council has identified synthetic SAF as the most promising measure to lower emissions of aviation and thus contribute to the national goal of reaching net-zero CO_2 emissions in 2050. The Federal Office of Civil Aviation has specified its vision for the role of SAF in a *Strategy promoting the development and use of SAF*.

The first element is the goal that by 2050 SAF shall contribute at least 60% to net CO_2 reductions in Swiss civil aviation. Secondly, it states that the development of SAF production pathways, especially synthetic ones, must be supported to realise their potential as quickly as possible. Thirdly, it outlines the need for flanking measures to facilitate a quick upscaling of SAF capacity. To reach these goals, blending mandates for SAF and possibly synthetic SAF as well as the provision of funding for the development of SAF production pathways (especially pilot and demonstration plants) are part of a legislative proposal which is planned to enter into force in 2025. In order to avoid market distortion within Europe, the blending mandates shall be aligned with the mandates defined under the ReFuelEU Aviation initiative of the European Union.

Türkiye

The Turkish government is planning to develop SAF dedicated regulations in the short-term, to create incentive opportunities and promote SAF producers in the country. The DGCA works on obliged blend ratios percentages to serve SAF on airports. There are national industry initiatives in the R&D phase, targeting to be in the production phase between 2025 and 2030.

United Kingdom

In July 2022, the UK government published their Jet Zero Strategy for the decarbonisation of aviation. Key SAF polices in the Jet Zero Strategy include implementing a SAF mandate of at least 10% by 2030, launching the GBP 165 million Advanced Fuels Fund to support first-of-a-kind commercial and demonstration plants, establishing a SAF clearing house, and delivering the first net zero transatlantic flight running on 100% SAF.

The UK government ran a consultation in 2021 on the introduction of a SAF mandate, and published a government response to this consultation in July 2022 which confirmed the high level principles that will underpin the mandate. These include the fact that the mandate will operate as a GHG emission reduction scheme with tradeable certificates, eligible fuels will be waste-derived biofuels, recycled carbon fuels and PtL fuels, and the mandate will include a HEFA cap and a PtL sub-target. The government response also announced a commitment to see at least five SAF plants under construction in the UK by 2025, as well as an intention to work with industry and investors to look at how to create the long-term conditions for investible projects in the UK. The government plans to publish a second SAF mandate consultation to confirm specific targets, timescales, and scheme design in 2023.

The UK also launched the Jet Zero Council in 2020 which is an industry-government partnership with the aim of accelerating the decarbonisation of the aviation sector. The Jet Zero Council has a SAF delivery group, which provides advice on how government and industry can work together to establish UK production facilities and accelerate the delivery of SAF.

3.3. The European SAF map

A European SAF Map is available at EUROCONTROL's public website with a selection of pioneering industry initiatives of SAF use in Europe, based on publicly available information. It also incorporates updated information of European State's SAF policies (as reflected in the *European SAF policy outlook* chapter above).

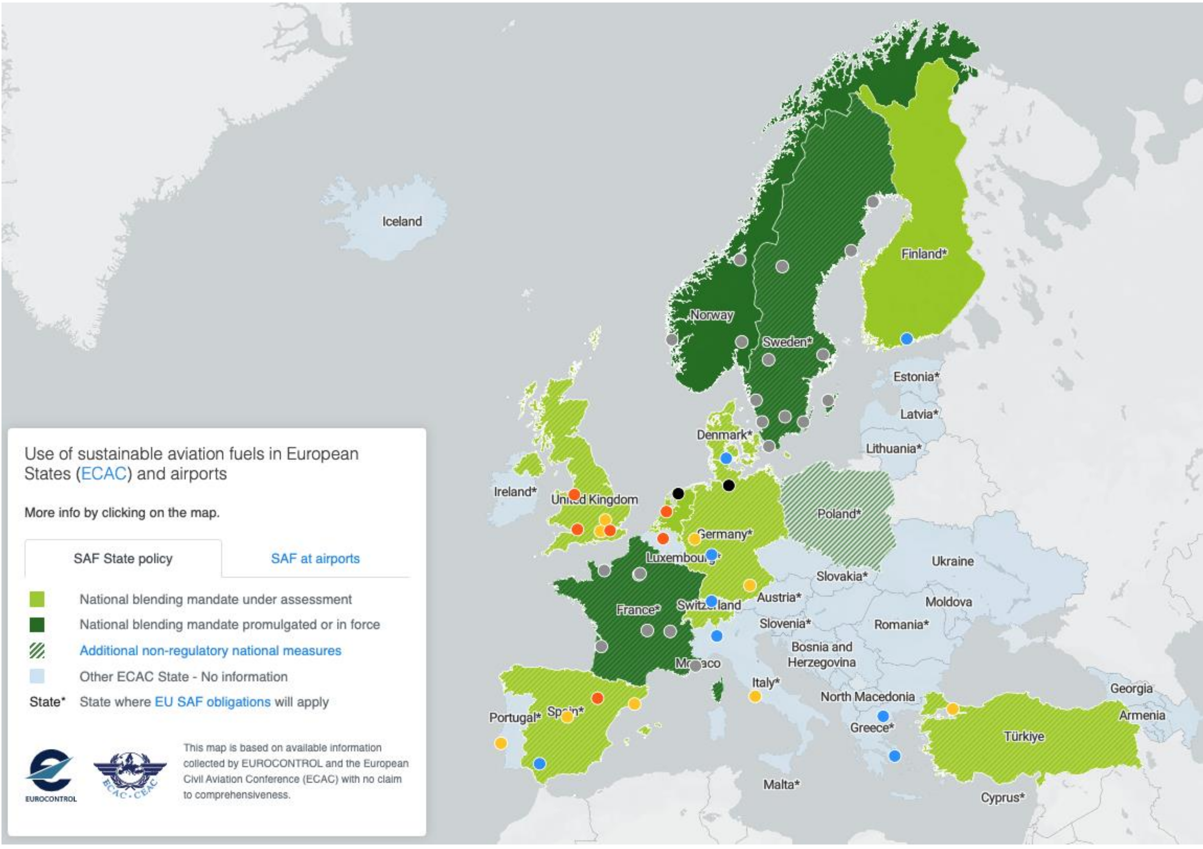


Figure 7: Appearance of the European SAF Map

This map will be regularly updated to showcase European action to make SAF a large-scale reality and motivate others. For a more detailed view and updated information please go to the website: https://www.eurocontrol.int/shared/saf/

4. SAF potentials in Europe

Large-scale development of SAF boosted by public policies can generate economic and social benefits, beyond the environmental ones described in Chapter 1.4 above (SAF benefits).

Feedstock can be available from many different sources as also shown in Chapter 1.3 (technology options) which gives most countries the possibility of identifying potential production opportunities to feed SAF industrial value-chains.

The development of SAF large-scale markets will require the expansion of new industrial capacity, generating jobs and economic growth. According to the Air Transport Action Group (ATAG), it is estimated that up to 14 million jobs could be created or sustained by the shift to sustainable aviation fuels, creating new energy industries around the world: whereas 90% of fossil fuels come from just 22 countries today, sustainable alternatives could open up opportunities in almost every country[74].

The ReFuelEU Aviation impact assessment estimates that the implementation of the SAF mandate in the EU could generate significant net job increases, largely driven by the high employment needs of the SAF industry from 2030 to 2050. Combining employment effects in the air transport and SAF industries, it could generate close to 100 000 net additional jobs in 2040 and around 200.000 in 2050.

This chapter highlights different industrial potentials in Europe for the development of large-scale SAF markets and helping policymakers identify opportunities for their countries.

4.1. Feedstock and industrial potentials in Europe.

In Chapters 1.2 (SAF qualification) and 1.3 (Technology options) it is underlined that aviation will move from relying on fossil fuel towards being powered by SAF produced from a variety of renewable biomass feedstocks and renewable electricity sources.

Such flexibility provides opportunities to States to develop SAF promotion policies, to identify feedstock and technology potentials in their territories which could feed SAF value-chains and generate opportunities to their industries and citizens.

The two main industrial enablers identified in the European aviation industry roadmap Destination 2050, are the availability of biomass feedstocks, especially in the short and mid-terms, and renewable electricity in the longer run.

Sustainable biomass feedstocks

Sustainable biomass feedstocks can be of agricultural, forestry and (non-recyclable) waste origins, including for example used cooking oil, agricultural and forestry residues, part of municipal solid waste, or energy crops whose primary target is the production of energy. The aviation industry decarbonisation roadmaps as well as the EU policy proposals for SAF upscale are only targeting biofuels produced from non-food/feed crops or residues.

74 https://www.atag.org/our-activities/sustainable-aviation-fuels.html

Renewable electricity

Renewable electricity is expected to play a key role in the decarbonisation of aviation either to be used in the long-term to produce hydrogen and hydrogen-derived fuels as aviation fuel or to directly power hybrid/electric aircraft.

But renewable electricity is expected to play a major role in the mid-term to produce synthetic aviation fuels (also called Power to Liquid (PtL) or e-fuels), a type of SAF which uses CO_2 as feedstock and water (to produce hydrogen) and need big amount of renewable electricity to be produced.

4.1.1. Sustainable biomass potentials

To scale up and commercialise SAF deployment sufficiently to achieve tnet zero carbon emissions by 2050, the aviation industry considers the establishment of a diversified and sustainable feedstock base crucial. This would combine biofuels from non-recyclable wastes, residues, and non-food (lignocellulosic) crops as well fuels of non-biological origin, (such as PtL, e-fuels, or Sun-to-Liquid also called Synthetic Aviation Fuels) from renewable electricity and CO_2 sourced from direct air capture.

Sustainable biomass availability

The Destination 2050 roadmap estimates that the amount of bio-based SAF needed to achieve net zero carbon emissions will be 13 Mt in 2050 (considering that e-fuels will be a relevant part of the SAF mix contribution). The required biomass feedstock input would be 24 Mt, (the roadmap assumes a conversion factor of 55%), which is approximately equal to an energy content of roughly 1 EJ[75]. Depending on different biomass availability assumptions per year in 2050, achieving the roadmap's objectives would require between 4% and 12% of total biomass availability in the EU.

This share of biomass attributed to aviation is considered by the industry report both realistic and technically feasible, based on European resources only.

The European study *Assessment of the Feedstock Availability for Covering EU Alternative Fuels Demand*[76] published in January 2022, and targeting road, aviation, and maritime sectors, confirmed that the availability of sustainable feedstock may not be the major barrier today to cover the potential European demand for sustainable alternative fuels in 2030.

A key finding of the study is that whilst feedstock is present across European regions, a critical element which requires detailed analysis at the implementation value chain level is the effectiveness of its sustainable mobilisation alongside the synergies and trade-offs that may arise. The diversity of raw materials and the lack of focused support for the mobilisation of the preferred biowaste and residual streams adds difficulty to their availability.

75 Conversion factor = 0.04 EJ/Mt, 1 EJ = 1018 joules

76 Prussi M, Panoutsou C, Chiaramonti D. Assessment of the Feedstock Availability for Covering EU Alternative Fuels Demand. Applied Sciences. 2022; 12(2):740. https://doi.org/10.3390/app12020740

This publication shows categoriszation of feedstocks contained in different biomass assessment studies for the EU-27 and UK to contribute towards the 2030 policy targets, which is included below to illustrate the variety of biomass feedstock sources.

	Agricultural Feedstocks	Forest Feedstocks	Biowastes
JRC ENSPRESSO	biofuels crops from rotational arable crops also used for food and feed purposes (e.g., oil seed rape, sunflower, wheat, maize, etc.); primary residues from arable crops (straw and stubbles), pruning, cutting, and harvesting residues from permanent crops, dedicated perennial crops, energy maize and grassland cutting solid and liquid manure	stemwood for fuelwood, primary residues and secondary residues from wood processing industries (sawmill residues, which are generally converted in chips and pellets before they are sold further; saw dust; and black liquor)	Biomass fraction of municipal solid wastes (MSW) Mixed wastes of food preparation (including utilised cooking oil) Post-consumer wood Sewage sludge
DG RTD	crop residues from arable crops (straw and stubbles), pruning, cutting, and harvesting residues from permanent crops, dedicated energy crops (on below average quality land. Only the land that is released from other crops in a business-as-usual baseline has been used in the modelling for growing of energy crops).	stemwood, primary residues (stem and crown biomass from early pre-commercial thinnings. Logging residues from thinnings and final fellings; Stump extraction from final fellings and thinnings) and secondary residues from forest industries (sawmill residues, sawdust, black liquor).	Biomass fraction of municipal solid wastes (MSW) Mixed wastes of food preparation (including utilised cooking oil) Post-consumer wood Sewage sludge
Concawe	agricultural residues (primary residues from arable crops (straw and stubbles), pruning, cutting, and harvesting residues from permanent crops, dedicated perennial crops	stemwood, primary residues (logging residues-same with the DG RTD categories) and secondary residues from forest industries (sawmill residues, sawdust) post-consumer wood	Biomass fraction of municipal solid wastes (MSW) Mixed wastes of food preparation (including utilised cooking oil) Post-consumer wood Sewage sludge

Source: adapted from Concawe: Sustainable biomass availability in EU.

Table 7: Examples of biomass feedstock categories (Source: Prussi M. et al. See footnote [76])

The above referred research shows that there is considerable uncertainty on how the expected policies towards transport decarbonisation will be realized, and those will be further defined by the legislative initiatives that will be put in place. This results in a difficulty to estimate the sustainable biofuels potential demand in Europe. However, the study estimated the potential European demand for alternative fuels in the EU and UK ranged between 20 and 33 Mtoe by 2030.

Some feedstocks considered to be inducing direct and indirect emissions through land-use changes (such as lipid materials and food/feed feedstocks) are planned to be progressively phased out. This implies that a shift towards other productions will be needed to cover this expected cut in the feedstock pool. However, even when this general approach is focused on specific feedstock/fuel pathways, the overall picture does not change. The expected HEFA use in aviation could, for instance, be entirely supplied by waste streams.

The study also highlights that in the medium-term, forestry residues are expected to sustain growing demands, progressively reducing pressure on lipid materials, as technological conversion processes will be increasing their technology readiness level (TRL).

The following figure showing feedstock potential estimations (Mtoe) from selected European studies, illustrates that adequate quantities of sustainable feedstock can be made available to supply the development of SAF markets, among other low carbon transport fuel markets.

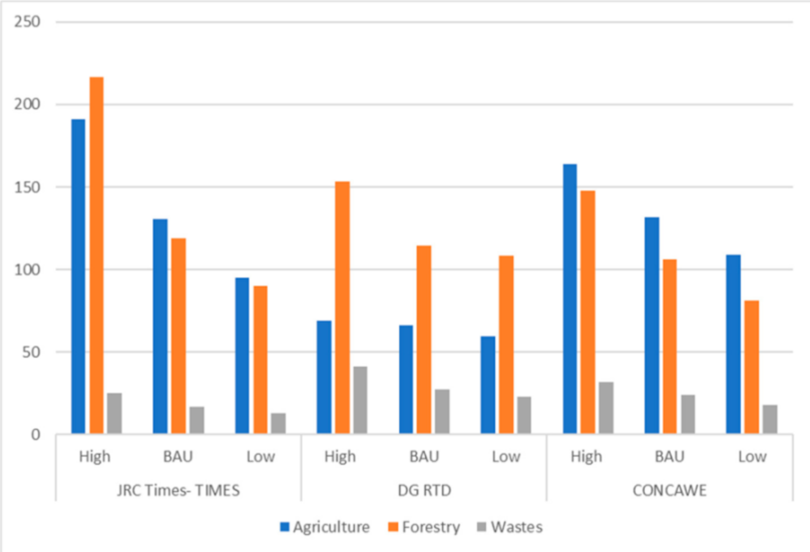


Figure 8: Feedstock potentials (Mtoe) from selected European studies (Prussi M. et al See footnote [76])

Refining industry estimations

A study published in August 2021 by Imperial College London Consultants, "*Sustainable biomass availability in the EU, to 2050*"[77], commissioned by Concawe, the refining industry's scientific & technical body, shows that the total potential of sustainable biomass availability in the European Union is more than sufficient to supply feedstock for bio-based liquid fuels to aviation, maritime and a share of road transport. The study also identifies opportunities and challenges for broadening biomass feedstocks.

	Opportunities	Challenges
Agriculture	New machinery Efficient crop management practices Precision farming New varieties better adapted to local agroecological conditions. Improved knowledge through smart applications and increased numbers of young farmers and entrepreneurs	Pressure to develop agricultural land for environmental benefits such as carbon storage, biodiversity, etc., Land degradation from soil erosion, nutrient depletion and salinisation, etc.
Forestry	There is a large untapped potential of biomass from forestry. According to Lindner et al. [37] the biggest potentials can be found in Germany, Sweden, France, and Finland. In addition, especially in Southern and Western Europe forest utilization rates are low and in half of the EU countries less than two thirds of annual increment has been harvested [38 39]. The potential could be further extended by developing technologies to access difficult terrains. Such terrains include steep slopes (especially in Central and Southern Europe) and peatlands (especially in Northern Europe). Digitalization and big data provide opportunities to radical innovations in biomass supply and logistics.	Climate change poses challenges to the whole European forestry. In Southern Europe droughts will be more common reducing growth and increasing risk for fires. In Northern Europe, on one hand, the increased temperatures will increase growth, but on the other hand the risk of natural damages will increase and the conditions for logging and transport deteriorate.
Biowastes	Increase awareness for biowastes collection among the public and especially in the young generation. Improve waste collection schemes across all Member States Use modern industrial separation technologies for maximising organic waste yield out of mixed waste streams.	Rising awareness for waste reduction and increase of recycling rates are expected to reduce biowaste availability at source.

Table 8: Opportunities and challenges for biomass feedstocks (Source: Concawe).

77 https://www.concawe.eu/wp-content/uploads/Sustainable-Biomass-Availability-in-the-EU-Part-I-and-II-final-version.pdf

4.1.2. Industrial potential capacity and scale-up needs.

Chapter 1.3 (Technology options) shows that there are different conversion processes suitable to use each feedstock, although there are different levels of industrial maturity for the available technologies.

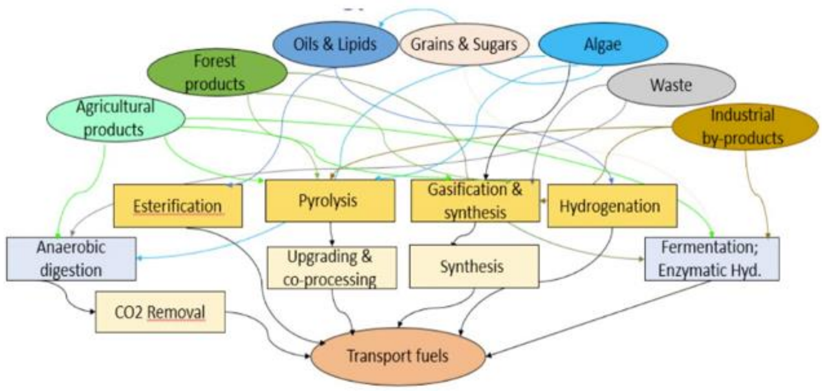
Current European potential SAF capacity is based on the Hydro-processed Esters and Fatty Acid (HEFA) technology, and the upper limit of the installed capacity can be considered approximately 2.4 Mt/year[78], although there are multiple projects[79] under development in Europe using Fischer-Tropsch, alcohol to jet to process Municipal Solid Waste or industrial waste gases and additional new pathways still under certification process.

The Concawe study developed by the Imperial College London referred above, identifies the following key findings with respect to the development of industrial capacity:

- On average it takes about two to two and a half years to build a First-of-a-Kind advanced biofuel plant from the moment that the financial package has been concluded.
- It can take between 6 months and 2 years to complete the commission of a First-of-a-Kind advanced biofuel plant once the construction has been completed.
- Experience has shown that on average it takes about 10-20 years to bring a technology from the lab scale to First-of-a-Kind status for advanced biofuel technologies.
- There are several abandoned First-of-a-Kind plants around the world and in practically all cases this had nothing to do with the technology itself. Corporate commitment, strong financing and existing supportive legislation are of paramount importance and have to be co-current and mutually supportive.

There is a very wide and complex variety of sustainable biomass industrial value-chains, but the status of the technologies' readiness levels are very different.

Figure 9: Complexity and flexibility of biomass value chains via conversion technologies and intermediate steps (Source: Concawe)



78 Prussi, M., O'connell, A., & Lonza, L. (2019). Analysis of current aviation biofuel technical production potential in EU28. Biomass and Bioenergy, 130, 105371

79 ECAC SAF Survey (February 2021): Reported one project in Finland, three projects in Norway, two projects in Portugal, one project in Spain and eight projects in the UK. More info: https://www.icao.int/environmental-protection/GFAAF/Pages/InitiativesAndProjects.aspx

The figure below, developed by the Concawe study, shows the status of advanced biofuels technologies based on their TRL level as well as their status based on the technology development roadmap:

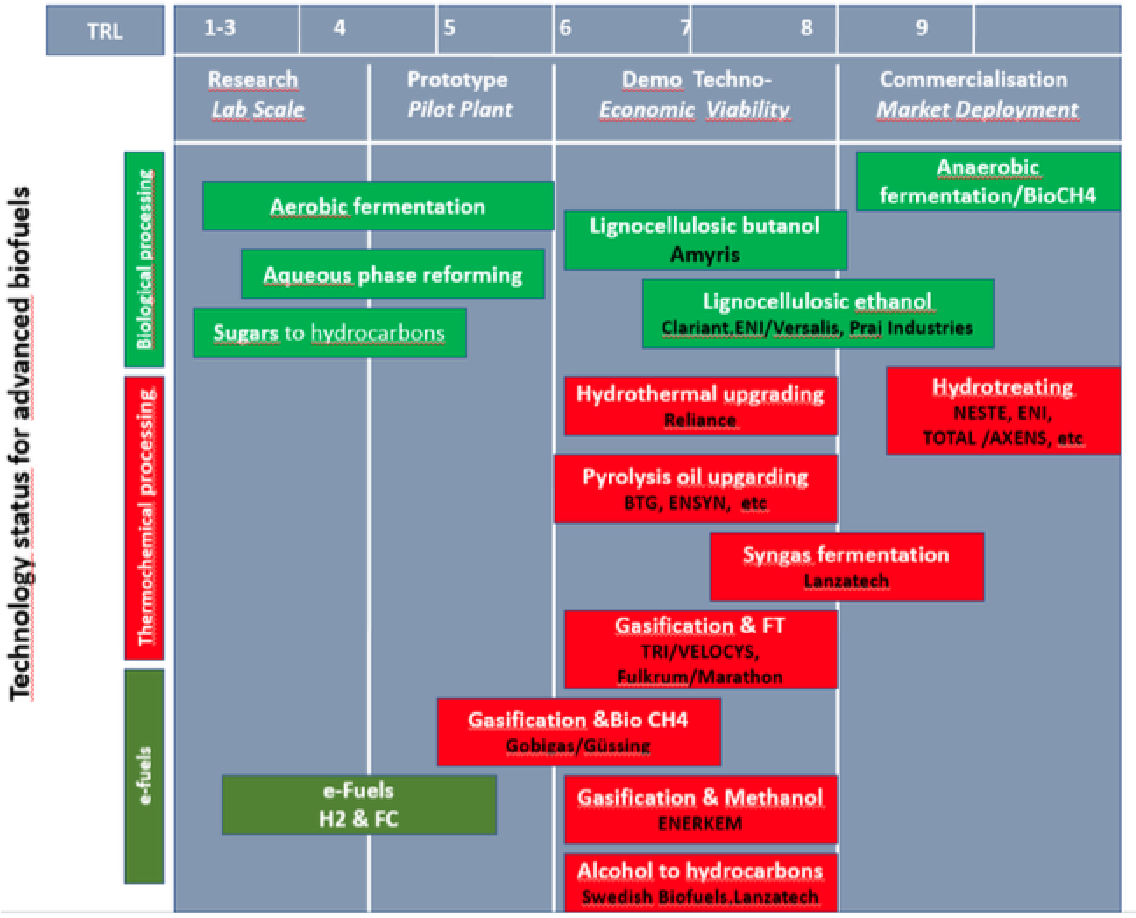


Figure 10: Status of advanced biofuels technologies based on their TRL (Source: Concawe)

Different production technologies can supply many fuel types including jet fuel. If production facilities make the necessary investments to optimise the jet fuel output, the amount of kerosene produced can become much larger than the amount of other fuels such as diesel.

SAF Rules of Thumb: Estimating costs, investments, and production potential

ICAO Committee on Aviation and Environment (CAEP) experts have developed a set of "*Rules of Thumb*"[80] for SAF that could inform policymakers and project developers for making order of magnitude estimations related to SAF costs, investment needs and production potential.

It should be noted that these SAF "Rules of Thumb" are intended to provide big picture trends for costs and processing technology/feedstock comparisons and could be utilised to make order of magnitude estimations. They do not provide precise cost or price information. As such, investment or policy decisions should be based on a dedicated analysis that captures specific details related to the investment or policy.

[80] https://www.icao.int/environmental-protection/Pages/SAF_RULESOFTHUMB.aspx

Three SAF manufacturing technologies were assessed: Gasification Fischer-Tropsch (GFT), alcohol to jet (ATJ) and hydro-processed esters and fatty acids (HEFA). For each of the technologies, multiple feedstocks and two levels of technology maturity were assessed: n^{th} plant and pioneer plant.

The Rules of Thumb provide the impact of feedstock cost, fuel yield, facility scale (total distillate and SAF), total capital investment (TCI) and minimum selling price (MSP) for n^{th} plant and pioneer facility scales. All of the information was calculated using US costs and financial assumptions. The values will change based on regional variables. No incentives were included in the MSP values calculated.

Summary tables and more detailed information is included on the ICAO Website[81].

[81] https://www.icao.int/environmental-protection/Pages/SAF_RULESOFTHUMB.aspx

Section II — Developing SAF policies

This Section contains SAF policy guidance and recommendations to ECAC States', based on the work of the SAF-TG, which considered the incorporation and adaptation to the European context of the Clean Skies for Tomorrow (CST) *SAF Policy Toolkit* recommendations of interest for ECAC States. The toolkit recommendations draw from the experience and diversity of the CST SAF Ambassadors group[82] and the wider CST community and that was presented at the UK 2021 UNFCCC COP26.

The toolkit is aimed at providing a helpful resource to policymakers around the world. It includes a range of policy options to support the scaled production and use of SAF in their countries and regions.

ICAO issued *Guidance on potential policies and coordinated approaches for the deployment of SAF*[83] in June 2022. This was prepared by the ICAO Committee on Aviation Environmental Protection (CAEP) and intended as a support reference for ICAO Member States seeking to develop SAF production or part of the SAF supply chain such as feedstock production.

It provides examples of SAF policies being utilised and considered around the world, which have also been considered in the development of this document.

The SAF-TG also considered recommendations emerging from discussions among the members of the OECD International Transport Forum (ITF)'s Decarbonising Aviation Common Interest Group (CIG), created in June 2021, funded by the European Commission, and co-chaired by Norway and Sweden. The group developed a *SAF Policy Vision* highlighting several priority areas that policymakers could consider targeting in the short-term to unlock the SAF growth potential. This Vision was presented at ICAO's 41st Assembly in 2022[84].

Policymakers are encouraged to undertake their own national analysis and adapt the recommendations contained in this Guidance to the local context before any implementation.

[82] Governments of Kenya, the Netherlands, Singapore, the United Arab Emirates, and the UK.
[83] https://www.icao.int/environmental-protection/Pages/SAF.aspx
[84] A41-WP/504 - a policy vision for promoting the scale-up of sustainable aviation fuels (SAF)

5. Considerations for creating a SAF strategy

Before implementing SAF policies, ECAC States should first develop a coherent national SAF strategy. A successful scale-up of SAF across diverse aviation markets is contingent on effective policies that promote their use and stimulate investments in production.

The following considerations may help inform policy direction and are aligned with the CST Policy Toolkit recommendations and consider the ITF Aviation Common Interest Group suggestions as well.

5.1. Gathering data and establishing a fact base

Due to the complexities of SAF feedstock and aviation sector operations, each country, region and market will need to develop its own fact base and analysis. From context-specific financial models to feedstock availability and renewable energy sourcing, it is essential for policy development to be uniquely adapted to its environment.

As an example, ICAO, with the support of the European Union, conducted a series of SAF feasibility studies in selected states in the Caribbean (Dominican Republic and Trinidad and Tobago) and Africa (Kenya and Burkina Faso) to understand their potential capacity and propose roadmaps to develop local supply chains, as part of the ICAO-EU assistance project *"Capacity-building for CO_2 mitigation from international aviation"*.

Those feasibility studies are a good example of gathering data and fact base analysis and are available at the ICAO website[85].

The ICAO Assistance, Capacity-building and Training for Sustainable Aviation Fuels

The *ICAO Assistance, Capacity-building and Training for Sustainable Aviation Fuels* (ACT-SAF) programme was officially launched on 1 June 2022, to provide tailored support for States and to facilitate partnerships and cooperation on SAF initiatives. The ICAO Assembly Resolution A41-21 welcomed this programme.

ICAO issued the State Letter ENV 9/1 – 22/56 (24/May/2022), which invited ICAO Member States to join the ICAO ACT-SAF. The States and Organisations that have expressed the intention to actively participate in ACT-SAF are listed in the ACT-SAF Platform.

Further European partnerships and feasibility studies as the ones highlighted above, can be promoted under ACT-CORSIA and with the support of the *ECAC Capacity-Building Programme for Environment*.

[85] https://www.icao.int/environmental-protection/pages/SAF.aspx

5.2. Setting a vision for promoting SAF

Governments can influence market expectations by setting ambitious targets for national or regional SAF production and consumption.

Chapter 3.2. about European States' policies presents examples of European States having established SAF targets, as the EU is doing at regional level, including via ReFuelEU Aviation.

Establishing additional national targets in ECAC States or an ECAC collective SAF use aspiration would boost the market and industrial synergies at ECAC level.

Commitments – and the policies that deliver on them – should be long-term, reflecting the timeframes for investment. Governments should work closely with the private sector and international partners to ensure that national SAF goals reflect suitably high levels of ambition while limiting regional market distortions.

Early scale-up for cost reductions

Airlines that want to use SAF face high prices and limited supply, which constitutes the most significant barriers to short-term market growth today. Targeted policies to provide certainty (such as certainty in the price paid for SAF), reduce costs, and increase production volumes, are needed to sustain early market growth. Rewarding early adopters can support actors that are already rolling out SAF today despite the existing barriers.

Mechanisms to make supplying SAF more flexible, such as book-and-claim or mass-balance schemes, can reduce supply and logistic barriers at an early market stage when SAF availability is concentrated in a few locations. Such mechanisms enable suppliers to deliver SAF to a general fuel pool rather than to a specific airport or aircraft.

5.3. Developing national SAF roadmaps or transition pathways

As referred above, establishing suitably ambitious national goals for SAF use is a recommended best practice which sends a strong signal to the industry to boost the necessary investments. Achieving the goals requires developing appropriate regulations and incentives to support the scale-up of commercial production facilities and ensuring its economic viability and competitiveness.

The feasibility studies referred to above and developed under the ICAO and the EU assistance recommend the development of national roadmaps. Those are available in the ICAO website references to be consulted by States as outlines of national roadmaps.

Developing national SAF roadmaps or transition strategies has been a very valuable common practice in pioneering European States, as highlighted in Chapter 3.2. and are in most cases framed in wider national climate policies and objectives.

Its main final purpose should be to inform policymakers on the necessary actions that are needed to incentivise SAF and mobilise investments into SAF research, development, and pilot production.

Such roadmaps should consider short and long- term goals, suitable technological pathways according to a country's feedstock availability, regulatory mechanisms that need to be created or adapted, required infrastructure build-out, the role of national agencies, ways to build social awareness and legitimacy for SAF, and the scale of the public funds needed to deliver the strategy.

Additional guiding principles, meaning key factors a state might view as important to achieving the vision – such as taking a partnership-based approach or guaranteeing that SAF deliver GHG emissions reductions above a minimum threshold – may underpin it.

The value of partnerships to promote SAF

The SAF transition relies on strong partnerships between governments and industry stakeholders, both within and across markets.

Effective SAF policies embrace the expertise and capabilities of feedstock producers, fuel producers and suppliers, original equipment manufacturers, airports, and airlines. They also promote stakeholder consultation and involve local communities in projects. Promoting a shared responsibility for increasing SAF production and deployment further prevents a disproportionate allocation of compliance requirements on single actors.

Benefits beyond emission reductions

Countries that promote SAF may profit from domestic industrial development. The transition to SAF will diversify and decentralise fuel production. Many regions host bioenergy resources, and investments in fuels of non-biological origin such as PtL or Sun to Liquid offer opportunities to areas with high potential for renewable electricity generation or solar radiation and water availability. However, they also imply risks: harming biodiversity, adding to pollution and resource depletion and conflicts over land use, as well as negative social impacts. Any policy must acknowledge, assess and mitigate these risks.

Production sites will move closer to feedstock resources as SAF from advanced bioenergy and synthetic fuels gain market shares, offering opportunities for local value creation and employment opportunities. Mobilising new countries to produce SAF can also increase energy supply resilience and reduce dependence on fuel imports.

5.4. Flexible and inclusive policy

States will also need to consider whether their vision and roadmap should be sector-specific or whether aviation will form a part of a broader national strategy.

SAF in holistic decarbonisation strategies

Holistic decarbonisation strategies that embrace all transport modes and available technology options maximise emission reductions across transport sectors. The policy experience in several markets with biofuels to reduce emissions in road transport provide valuable lessons for promoting SAF.

Drop-in fuels are the main decarbonisation option for international aviation available today, while technology breakthroughs for hydrogen and battery electric aircraft are pending. Directing available drop-in fuels to hard-to-abate sectors, including aviation, while promoting alternative, more energy-efficient decarbonisation technologies in sectors where they are available can maximise emission reductions and energy savings across the economy. For example, electrifying road vehicles may reduce the sector's reliance on biofuels and unlock feedstock for SAF production in some contexts.[86]

As a minimum, an aviation strategy should align with other sectoral strategies to ensure there is no domestic market distortion or unnecessary competition for resources. Further, broader sectoral strategies would do well to include focused guidance on SAF, in particular due to its complexity, as vague energy or renewable fuel incentive frameworks may not adequately address its unique set of challenges.

5.5. Managing risk

States should explore ways to identify and mitigate the associated risks deriving from their SAF strategy, including whether it delivers genuine carbon savings or leads to unintended outcomes. Such unintended outcomes could be negative impacts on biodiversity, pollution or natural resources; or competitive distortions that could financially hurt national carriers or pose a significant burden on public budgets, both of which could lead to discontinuing support..

Safeguarding credible emission reductions

Countries may choose different strategies and policy designs to promote SAF, depending on their specific market background and feedstock availability. Despite varying approaches, all policy designs should maximise emission reductions and prevent unintended sustainability impacts, including indirect land-use change (ILUC). To maximise climate benefits, policies should consider the quantity of avoided emissions rather than only the volume of SAF production. Policies may consider targeted support for advanced fuel technologies with high emission abatement potential that are comparably expensive today but have a high scalability potential in the longer term.

Existing carbon accounting methods, sustainability criteria and monitoring measures are not always harmonised. Aligning these is an enabler for the emergence of an international SAF market. It also eases compliance with various regulatory or voluntary frameworks for internationally operating airlines.

5.6. National, regional and international cooperation

It takes the entire value chain to create a SAF market at scale. Extensive multilateral and peer-to-peer interaction between governments, industry, consumers and NGOs will be needed to accelerate SAF deployment. Collaboration can range from aligning best practices on

[86] For example, in October 2022, the European Parliament and Council of the EU reached an agreement ensuring all new cars and vans registered in the EU will be zero-emission by 2035.

sustainability standards to considering how to best close the price gap between SAF and conventional jet fuel.

It is crucial for States to continue participating in regional and international dialogue and facilitate harmonisation. Given aviation's inherently international status, this approach can accelerate SAF adoption while mitigating carbon leakage risks and competitive distortions.

6. Policy options to support the development of a scaled SAF market

The ICAO Guidance on potential policies and coordinated approaches for the deployment of SAF[87], highlights the need for long-term policy frameworks for SAF uptake. The most suitable policies, however, are likely to vary for each country according to their geographic, economic, social and political characteristics.

European States that already possess a mature renewable fuel industry and comprehensive carbon emissions legislation might choose different policy levers from those looking to take their first SAF steps.

As underlined in the CST Policy Toolkit, no individual policy will drive SAF growth on its own. A range of supply, demand and enabling policy instruments aligned to each country's circumstances in terms of feedstock availability, value chain maturity, energy dependency, and climate goals need to be planned and implemented in a coordinated way.

It is necessary to seek a balance between supply and demand policies to preserve market equilibrium and avoid possible carbon leakage, where aviation markets would move from a country with stringent policies, to a country that is more lenient, leading to an overall increase in greenhouse gas emissions.

This section highlights several policy options and examples that could be used to support SAF production and use, following a structured framework as per the following Figure.

Further detailed considerations related to many of these policies can be found in the CST Policy Toolkit.

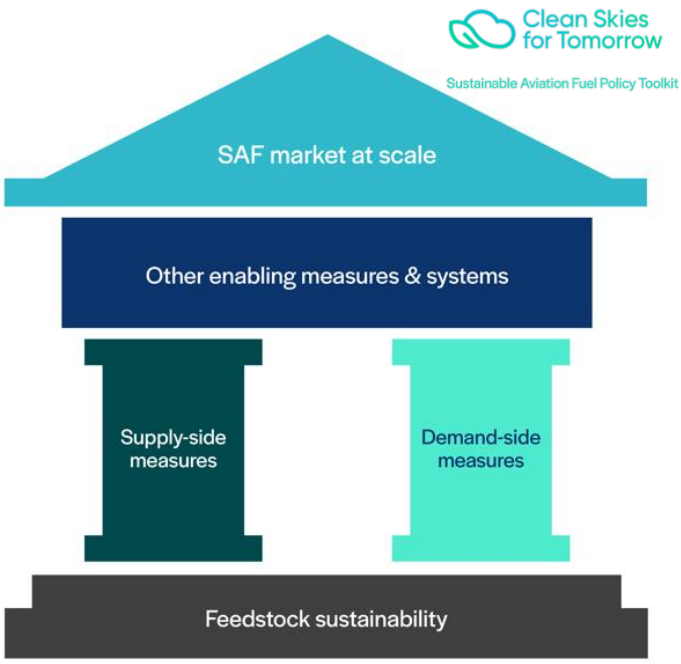


Figure 10: Overview of a regulatory framework for a SAF market (Source: Clean Skies for Tomorrow and Agora Energiewende, 2021)

87 https://www.icao.int/environmental-protection/Documents/SAF/Guidance%20on%20SAF%20policies%20-%20Version%201.pdf

6.1. SAF feedstock sustainability

For SAF to function as a sustainable alternative to fossil fuels, it must be produced from sustainable feedstocks that significantly reduce GHG emissions on a full life-cycle basis and do no harm to biodiversity, pollution objectives or natural resources. A set of policies that ignores this principle, risks both nullifying the positive environmental effects expected from producing SAF and economically undermining the value chain built for it.

Chapter 1.1 highlights that there is not a single applicable sustainability standard to SAF feedstock, as it will mainly depend on the applicable regulatory context, but a global reference standard is the ICAO CORSIA Sustainability framework,[88] which is the result of a global scientific and political consensus in ICAO to ensure the environmental and socio-economic integrity of SAF.

Supporting global SAF production requires a range of feedstocks as no single feedstock can sufficiently meet every need. Environmental and social integrity and supply chain verification, however, are crucial to selecting the suitable feedstocks as SAF must not threaten food security, result in direct or indirect land-use changes, or have a negativeenvironmental footprint from production.

The ICAO CORSIA sustainability criteria describe the specific conditions to be met and assessed by feedstocks to be eligible under the standard, grouped in 14 sustainability themes covering environmental and socio-economic areas to protect.

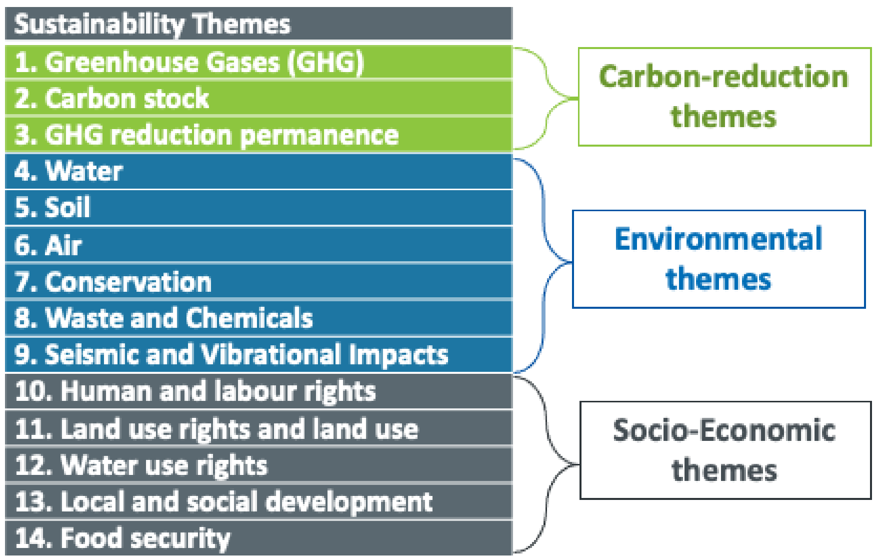


Figure 11: Sustainability Criteria for CORSIA Eligible Fuels

In the short-term, as the industry scales, policy frameworks will need to pragmatically balance feedstock availability and sustainability and build in flexibility to adapt as technology and feedstock supply evolve. However, it is extremely relevant to set out long-term visions (as recommended in Section 5.2), to minimize the risks of reaching dead ends.

[88] https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

6.2. Supply, demand and enabling policies

The CST Policy Toolkit uses an issue tree as a policy aid, sectioned into supply, demand and enabling branches, with potential decision pathways and policies detailed on each branch. Policymakers can use this decision-making aid to conduct their own cost-benefit and regulatory impact analysis.

The ICAO *Guidance on potential policies and coordinated approaches for the deployment of SAF,* includes eight qualitative metrics which can be used by States for assessing policy effectiveness and identify potential policies which have been demonstrated to be feasible, effective, and practical, the three key parameters influencing policy effectiveness. The qualitative metrics proposed are to be used as a "check-list" instrument for States in evaluating actual or potential policy options, as a tool to assess the feasibility, effectiveness, and practicality of applying such options to the national context and conditions.

The figure below represents the CST issue tree including key potential policy options.

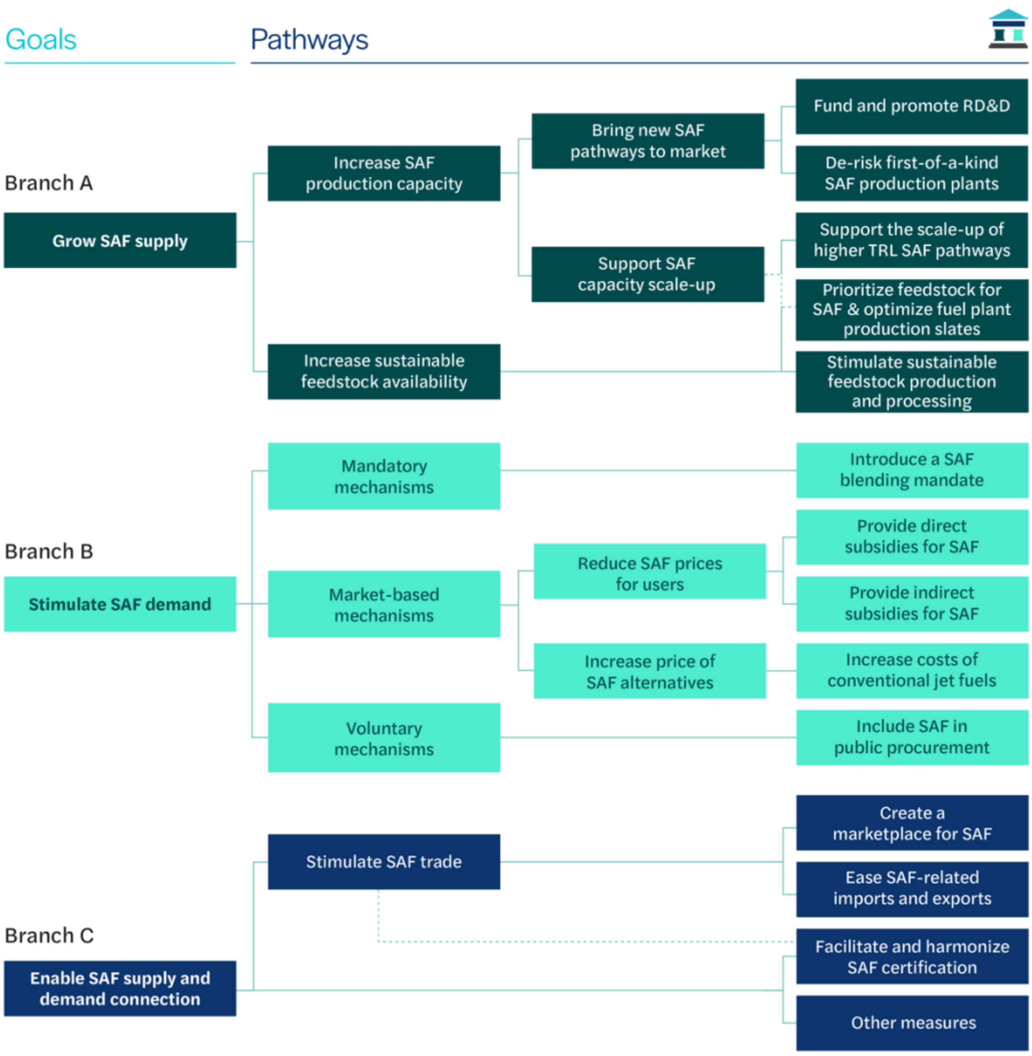


Figure 12: Issue tree with supply, demand and enabling measures for a SAF market at scale (Source: CST SAF Policy Toolkit)

6.3. Branch A: Stimulating growth of SAF supply

Branch A outlines possible policies to grow the sustainable supply of SAF through increased production capacity and feedstock availability. Further implementation details and considerations for the policies below can be found in the CST Policy Toolkit.

6.3.1. Fund and promote SAF RDD&D

Public research, development, demonstration, and deployment (RDD&D) investments in emerging SAF technologies are critical to broader feedstock availability, increased SAF production and lower prices. Government funding can also support technology demonstration and deployment across the SAF supply chain and enhance sustainability or improve yields in feedstock production, fuel conversion, and logistics.

Policy option 1: Establish dedicated innovation funds or financing options to support early-stage SAF production pathways at lower technology readiness levels (TRL)

Public support for SAF RDD&D may include funding for academic research and addressing innovation challenges, often with defined target feedstock types and conversion processes. Support can occur from establishing specific programme s or supporting existing private research activities or through universities or similar institutions.

Governments can also conduct RDD&D at their institutions and make the results available to all stakeholders. Such mechanisms can easily be put in place and governments can target public investment and limit it to the time needed to upscale early-stage projects.

Example:

- Horizon Europe[89], the EU research and innovation programme, offers grants for supporting research and innovation for enlargement and deployment of SAF technologies, including PTL, algae, STL and other potential new routes with up to EUR 44 million in 2023.

6.3.2. Support first-of-a-kind SAF production plants

Novel SAF production pathways have the most sustainable sources of feedstock. The technology and market risks associated with developing these less mature pathways, however, might be a barrier to private investment.

Tailored public support for investments will be needed to de-risk first-of-a-kind SAF production facilities. Financing programmes and tax policies that reduce the financial risk and tax burden of SAF projects will support private sector capital investment in SAF production.

Public support may include funding for loan guarantees, investment de-risking agreements, and capital grants, blended finance agreements, contract for differences (CFD) or other fiscal incentives for private sector investors.

[89] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

Policy option 2: Establish contract-for-difference (CfD) schemes to reduce the price gap between SAF and conventional jet fuels based on life-cycle assessment (LCA) of GHG emissions

There are a variety of de-risking mechanisms possible for SAF production facilities, with the most appropriate depending on the value-chain positioning of the institution bearing risk. CfD programmes aim to bring long-term certainty to investors and other renewable energy schemes already use them. By guaranteeing purchase, they minimise investment risk by locking in demand to return capital investments.

They are used to partially, or entirely, bridge the price gap to fossil fuels by providing guarantees to fuel producers that governments (and ultimately customers) will pay the difference between the market price of conventional fuels and the price needed to produce cleaner alternatives. Often, a competitive reverse auction determines a "strike price". If the market price the producer receives is lower than this strike rate, government funds meet the difference.

Example:

- The SDE++ (stimulation of sustainable energy production and climate transition) programme in the Netherlands provides subsidies via CfD for the use of techniques for the generation of renewable energy and other CO_2 reducing methods. The programme has a subsidy intensity limit varying from EUR 60-300 /tonne of CO_2 avoided. CfDs will be awarded for a period of 12-15 years and a competitive tender will select recipients.

6.3.3. Support the expansion of SAF infrastructure and high TRL pathways

SAF production infrastructure and SAF production facilities with higher technology readiness levels (TRL) pathways are likely to face higher financing and operating costs and requirements due to higher perception of investment risk than existing fuel suppliers.

Enacting financing programmes and tax policies that reduce the financial risk and tax burden of SAF projects will support private sector capital investment in SAF production.

Public support policies to de-risk investments and promote a level playing field with conventional jet fuels are necessary to lower investment outlays and accelerate SAF production deployment rates. As with low-TRL technologies, these mechanisms could take many forms, including blended finance agreements, grants and loan guarantees, contracts for difference, and more.

Policy option 3: Provide a combination of up-front capital grants and low-interest loans for the building and running of SAF production facilities to attract private investments

Fiscal incentives and public financing, together with blending mandates, are the most widespread policy instruments used to promote renewable fuel production, distribution and consumption. De-risking measures via risk diversification can be just as effective in crowding-in supportive investments.

Capital grants, which are commonly used in renewable energy projects to cover development costs, reduce the financial needs and financial risks of the targeted investment. A government grant given to an entity to build or buy SAF-specific infrastructures can support a range of production facilities, transportation, re-fueling or blending facilities.

Low-interest loans backed by a government institution, helps the project finance case by reducing the weight of debt costs, notably on the first years' cash flows – if they include a grace period – and spread-out investment costs over the asset's economic life, lowering the cost of capital.

Examples:

- The United Kingdom Green Fuels, Green Skies (GFGS) Competition supported first-of-a-kind SAF plants, with up to GBP 15 million in grant funding on offer in 2021/2022.
- The United Kingdom Advanced Fuels Fund (AFF) provides GBP 165 million in grant funding between 2022-2025 to support SAF projects.
- The EU Innovation Fund and Breakthrough Energy Catalyst also offer examples of this type.
- The US Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Programme provided loan guarantees of up to USD 250 million to fund up to 80% of the total eligible project costs for the development, construction and retrofitting of commercial biorefineries and biobased product manufacturing facilities. The US government has announced a further USD 3 billion in loan guarantees to scale up SAF projects.
- Brazil's Renovabio Programme provides low-interest loans of up to BRL 100 million to biofuel producers via the National Bank for Economic and Social Development. A grace period of 24 months is granted, and interest rates are linked to CO_2 emissions reduction targets set by the programme.

Policy option 4: Eligibility of SAF for tax advantages and blending or production incentives

Governments can establish different tax benefits that reduce the tax burden of SAF, promoting this way capital investment in SAF production.

For States that tax domestic jet fuel consumption, a reduction or elimination of the tax in proportion to the quantity of SAF consumed serves to incentivise SAF purchase.

Incentives targeted at the producers, providers or blenders of fuel that provides a credit against taxes, would mitigate the cost of production or purchase the difference between SAF and fossil jet.

Examples:

- In the EU, the European Commission proposed in 2021 that kerosene used as fuel in the aviation industry will no longer be fully exempt from energy taxation for intra-EU trips. Over a period of ten years, the minimum tax rates for these fuels will gradually increase while sustainable fuels for these sectors will benefit from a minimum rate of zero to foster their uptake.[90]

- In the US., an existing Blender's Tax Credit (BTC) provides a USD 1.25 per gallon incentive for blenders of certain types of biofuels with a GHG saving over 50%, with an additional USD 0.01/gal per each additional 1% GHG saving up to USD 1.75/gal.

- France has established a mandatory 1% SAF supply from 2022 by increasing the scope of an existing regulatory tool, the so-called incentive tax relating to the incorporation of renewable energy in transport.

Policy option 5: Bonds/Green bonds

Bonds or *green bonds* can be issued by private companies, supranational institutions, and public entities including sub-national and local governments to provide low-interest rates and tax-exempt financing used to support fuel production infrastructure build out. Green Bonds are designed specifically to support specific climate-related or environmental projects.

Example:

- The US States of Nevada and Oregon issued bonds in support of prospective SAF producers.

Policy option 6: Support for feedstock supply establishment and production

SAF production may be limited by availability and cost of the raw material (feedstock) from which it is produced. Targeted support can address the risks and costs to feedstock suppliers by establishing a new crop and producing it under uncertain conditions. Crop insurance programme support for SAF can also be considered in addition to subsidy payments made to feedstock producers aimed at incentivising production.

Example:

- The US Biomass Crop Assistance Program (BCAP) offers annual incentive payments and establishment payments to producers of biomass crops intended for bioenergy production.

6.3.4. Prioritise feedstock for SAF production & optimise conversion yields

The demand for bioresources is increasing significantly as different sectors look to biomass feedstock to provide their decarbonisation solutions. Sustainable options are available but require strategic allocation.

[90] https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3662

Demand from competing sectors such as power and road transport can constrain the availability of renewable feedstock for SAF production or the fraction of SAF produced at renewable fuel plants. Aviation remains highly dependent on renewable liquid fuels for the immediate to medium-term. Others, however, have alternative decarbonisation options through renewable electrification.

Policy option 7: Support the development of non-bio-based decarbonisation options in competing sectors to incentivise the redirection of feedstocks and national renewable fuel production for aviation

SAF volumes could increase significantly in the short-term if renewable fuel producers shift existing fuel production to jet fuel.

To stimulate the shift without harming existing markets, governments need to gradually reduce demand for renewable resources in competing sectors where other decarbonisation options are closer to cost competitiveness. Transitioning to clean electricity as the main source of final energy can, in fact, represent an opportunity for governments, as it is currently the cheapest and most efficient way to promote the decarbonisation of economies.

Policy priorities to electrify competing industries are sector and region dependent; policymakers must find the framework that is most appropriate to their larger energy transition strategy and localized context.

For example, policies could drive the transition for light-duty vehicles via charging infrastructure investment, purchase incentives for battery electric vehicles, fuel economy standards, and bans on or the phased retirement of internal combustion engine vehicles.

Example:

- In October 2022, the European Parliament and Council of the EU reached an agreement ensuring all new cars and vans registered in the EU will be zero-emission by 2035 (i.e. phasing out of internal combustion engines)..

6.3.5. Stimulate sustainable feedstock production and valorise SAF benefits

Feedstock production and collection is expected to be one of the most labour-intensive areas in the SAF value chain. Moreover, not all countries or regions will have the same production capacity and there is a risk that producers will simply import the lowest cost feedstock available, potentially resulting in carbon leakage.

In the long-term, as SAF increasingly replaces fossil jet fuel, local feedstock supply for local production is an important factor for an efficient global market. However, it takes several years for feedstock supply chains to reach optimal levels, so local production needs incentives today if countries want to achieve ambitious SAF goals for 2030 and 2050.

SAF production and use may also create a number of environmental benefits and ecosystem services mainly related with feedstock production, that can be recognized and valued under existing and new policies. These could include carbon benefits and greenhouse gas emissions reductions; air quality improvements; and contrail reductions. Additional benefits may be identified going forward.

Policy option 8: Grant tax exemptions for SAF with a focus on the regional location of production and the provenance of the feedstock while ensuring strict sustainability criteria

If well monitored, controlled and enforced, such incentives can encourage sourcing of biomass and renewable feedstock from local and regional producers, stimulating local economies and maximising supply chain logistics efficiencies. Moreover, by specifying which feedstocks will be eligible for incentives, governments can stimulate the production and collection of the most sustainable feedstock for the local area, avoiding fuel production from environmentally sensitive areas, such as peatlands, wetlands and primary forests.

Example:

- Brazil's National Biodiesel Production and Use Programme provides tax incentives for biodiesel producers who purchase feedstocks from family farmers. The minimum purchase percentages for eligibility vary from 20% to 40% according to the region's socio-economic status.

Policy option 9: Recognise SAF benefits under carbon taxation or cap-and-trade systems

Where a jurisdiction has introduced a carbon tax, carbon price, or carbon levy (that is setting a tax rate on carbon emissions for each fuel type, thereby providing a signal to reduce emissions) SAF could be rated as either zero or in proportion to the life-cycle greenhouse gas emissions benefit of the particular fuel, thereby subject to reduced tax. This differs from a cap and trade system by not stipulating an overall emission reduction target.

Cap-and-trade systems limit total GHG emissions by setting a maximum emissions level and allowing participants with lower emissions to sell surplus emission permits to larger emitters. This system creates supply and demand for emissions permits and establishes a market price for emissions and a value for avoided emissions. When SAF are used in such a system, it exempts or reduces the obligations of the user of the SAF under the regulation.

Examples:

- Under the European Union Emissions Trading System (EU ETS), SAF meeting the EU RED II criteria are rated as zero (biogenic, but others are likely to be added).

- An operator using SAF can reduce its CO_2 offsetting obligations under the ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Policy option 10: Recognise non-carbon SAF benefits such as improvements to air quality or reduction in contrail formation

Programmes and incentives can place a value on local air quality. SAF could be able to financially participate in these incentive schemes based on air quality benefits that certain SAFs may be able to provide.

As the understanding of the science evolves, reductions in contrail formation resulting from use of SAF may be recognised for their environmental benefits.

6.4. Branch B: Demand-side measures to stimulate SAF uptake

Branch B explores policy options to increase SAF demand by mandatory market-based, and voluntary instruments, including creating mandates for SAF use in the transportation fuel supply, providing incentives or subsidies that reduce the cost of SAF for consumers, and voluntary commitments to use SAF. As for Branch A, further implementation details and considerations for the policies below can be found in the CST Policy Toolkit.

6.4.1. Update of existing policies and creation of SAF blending mandates

The cost differential between SAF and conventional jet fuel is expected to narrow as economies of scale and learning effects take hold, but cost competitiveness is unlikely to be achieved without policy support or correction of markets failing to effectively price environmental impacts.

Policies aimed at creating long-term, predictable demand to de-risk investments in supply chains are key levers for widespread SAF deployment.

Policy option 11: Establish a SAF blending mandate with a blending level that increases progressively over time

Blending mandates create an obligation on one or more parties in the value chain – fuel suppliers, blenders, airports, airlines – to increase the share of SAF in the jet fuel market, sending an unequivocal market demand signal without imposing direct burden on public funds.

Policies that require SAF to become available as part of the transportation fuels supply can take different approaches such as setting volumetric requirements or fuel supply greenhouse gas emission reduction targets.

An obligation on fuel providers to provide increasing SAF fuel volumes added to the existing fuel supply or to reduce its carbon intensity (life-cycle greenhouse gas emissions intensity) on a multi-year schedule, creates an incentive for production of more SAF and other fuels which meet the sustainability requirements of the programme.

Examples:

- The Norwegian government established a blending obligation to aviation fuel suppliers for a 0.5% minimum content of advanced biofuel from 1 January 2020.

- The Swedish government has established a regulation for GHG emissions reduction obligation for jet fuel suppliers to promote the use of SAF after 1st August 2021.

- The French government established an annual blending obligation to aviation fuel suppliers for a 1% minimum energy content of biofuel produced from non-food or feed crops, starting from 1 January 2022 and which should be revised annually.

- The European Commission presented in July 2021 the ReFuelEU Aviation proposal, aimed at boosting the supply and demand for SAF in the EU, through a blending obligation on fuel suppliers to EU airports (see Chapter 3.1).

- The UK will introduce a SAF mandate from 2025, requiring at least 10% (c1.5bn litres) of fuel to be made from sustainable sources by 2030.

Policy option 12: Update existing policies to incorporate SAF

States may have existing renewable fuel incentive policies at a national sub-national, regional or local level that could be adapted to incorporate SAF as qualified fuels.

Typically, legacy biofuel policies have focused on road-transport-appropriate fuels and do not include SAF as an option. With the more recent advent of drop-in jet fuel/SAF production technologies, an update to these existing policies to support SAF production can provide additional incentives that contributes to SAF economic viability.

Examples:

- The Netherlands has had an *opt-in* for SAF to be eligible for the fuel supplier's obligations under the EU Renewable Energy Directive (RED II) since 2013 and the UK did as well in 2017 by including SAF into the market trading mechanism (MTM) of the Renewable Transport Fuel Obligation (RTFO).

6.4.2. Provide direct or indirect subsidies for SAF

Direct public subsidies can help address the cost disparity between SAF and conventional jet fuels by reducing SAF production costs or discounting the price for buyers. Subsidies to support price competitiveness are particularly important when environmental harms from fossil fuels are not properly accounted for. Subsidies are widely used to promote solar and wind generation capacity and have been credited with increasing innovation, scaling up volumes and reducing reliance on fossil fuels in other sectors.

Indirect subsidies also aim to address market inefficiencies and reduce the price disparity between SAF and regular jet fuels but, unlike direct subsidies, do not provide a specific monetary pay-out to the beneficiary.

Policy option 13: Provide direct tax incentives for SAF offtakers, producers or blenders to reduce the cost differential between SAF and conventional jet fuels

Governments can provide tax incentives based on units of qualifying SAF produced, blended or used above a pre-determined minimum life-cycle emissions savings threshold. The higher the emissions reduction per unit of fuel beyond this threshold, the larger the tax incentive.

This approach aims to stimulate the production of SAF from technologies with higher GHG savings potential, targeting spending towards only the most impactful technologies. Such tax incentives can have immediate impacts on SAF costs and can be adjusted as SAF production reaches economies of scale.

Example:

- The Second-Generation Biofuel Producer Tax Credit (SGBPTC) in the US, allows a credit against the fuel producer's tax liabilities of up to USD 1.01/gallon of second-generation biofuel, such as from lignocellulosic, sold and used by the purchaser.

Policy option 14: Levy a dedicated SAF fee on flights to finance SAF acquisition, with possible variation accounting for flight distance and SAF blending target levels

Charges and fees are common in aviation and customers generally pay them at the point of ticket purchase. A dedicated SAF fee could allow airlines and partners to bridge the cost differential of procuring SAF and simultaneously improve awareness and transparency for customers on SAF's increasing role throughout the aviation sector.

A central institution could procure SAF, such as through reverse auctions, and blend it with regular jet fuel within certified limits. When applied based on destination, such a fee would also ensure equal treatment for all airlines regardless of location and number of intermediate stops. Fees could be adjusted over time to reflect a rising SAF blending target and actual passenger numbers.

Example:

- French regulations set a SAF blending mandate of 1 per cent SAF on fuel suppliers from 1st January 2022. As a result, some airlines decided to include a SAF levy in their ticket price, such as Air France, depending on cabin class and distance.

6.4.3. Introduce disincentives for conventional jet fuel

Another way of achieving cost competitiveness for SAF is to increase the price of its immediate alternatives by incorporating social and environmental costs to fossil fuels.

Policy option 15: Introduce a domestic carbon price or cap-and-trade mechanism, potentially aviation-specific, to price-in the cost of GHG emissions for fossil fuel

A cap-and-trade system can be used to put a price on fuel emissions and encourage fuel switching to low-carbon alternatives. A cap is set on the total allowable GHG emissions by regulated entities, tightened over time to reduce total emissions. The initial GHG emission certificates can be allocated either via auction or based on historical production. If a participant exceeds its annual emissions cap (and has not purchased additional emissions allowances), fines are imposed.

Example:

- Under the EU ETS, air carriers must surrender carbon allowances from intra-EEA flights, each representing 1 tonne of CO_2, equivalent to their emissions reported in the previous year. The system reduces the allowable CO_2 emissions every year[91] and restricts the number of permits within the marketplace to drive polluters to progressively reduce their CO_2.

6.4.4. Include SAF in public procurement

A clear statement of policy direction and ongoing SAF purchasing are examples of government leadership that can generate ways to ramp-up SAF production and use by generating critical early demand, while also serving as a leading example for private offtakers.

Policy option 16: Policy statements and SAF supply goals to establish direction

Setting aspirational goals of specific production or use amounts to signal future intent to develop comprehensive SAF policy measures. This can be linked to the implementation of future policies, sending a signal for project planning and could include State level commitments for a quantitative SAF use goal or carbon reduction by a certain time, or signals from industry such as a commitment to achieve net zero by 2050.

Example:

- Several European State's policies (as reflected in Chapter 3.2) have established national objectives to promote the supply and use of Sustainable Aviation Fuels (SAF).

Policy option 17: Impose a minimum public SAF procurement quantity for military and state flights, and for commercial flights by public servants

A strong demand signal can be created by requiring national, state, local governments, and military to commit to renewable fuel/SAF procurement to reduce environmental impacts of air travel and operations.

Governments can procure SAF directly from fuel providers via competitive tenders for use on state-owned aircraft and indirectly from airlines by ensuring that public servants on commercial flights cover the price premium between regular tickets and tickets for SAF-fuelled flights. The participating airlines then should guarantee and provide evidence that the

[91] Currently by 2.2 % per year but in December 2022, the European Parliament and the Council of the EU agreed on a target of 62% reduction by 2030 with a linear reduction factor of -4.3% in 2024-2027 and -4.4% in 2028-2030.

publicly acquired SAF volumes will be put into circulation within a given timeframe. This encourages the growth of a lead market for SAF and is simple to implement in the short-term.

Example:

- The government of the Netherlands participates in KLM's Corporate SAF Programme whereby public servants flying on KLM pay the SAF premium difference.

6.5. Branch C: Enabling SAF markets

Additional activities may be necessary to bring clarity and certainty to enable SAF markets to function optimally. Branch C details possible instruments to connect and amplify the effectiveness of supply and demand measures by easing scaling barriers and promoting trade. As for branch A & B, further implementation details and considerations for the policies below can be found in the CST Policy Toolkit.

6.5.1. Create a virtual SAF marketplace

For SAF to reach global trading volumes similar to those of conventional jet fuels, large-scale production and harmonised technical and sustainability specifications are needed in addition to corresponding market mechanisms to ensure efficient trade of SAF and its environmental attributes.

The creation of a national, regional or global SAF marketplace could expand the typical bilateral relationship between producers and buyers, providing better information and competitive prices to end-customers. Improved supply-chain transparency could allow offtakers to source SAF volumes and their virtual attributes from their more economically advantageous points, in turn stimulating SAF production from the most efficient technological pathways, most sustainable feedstocks, and most socio-economically responsible processes.

Creating a virtual SAF marketplace also comes with some important risks and issues, such as risk of fraud, need for centralised trading entity and standards for accounting, and the risk that SAF production develops only in States where production is the cheapest therefore missing any desired local benefits from SAF production.

Policy option 18: Establish or recognise an existing environmental attribute ownership transfer system, such as book and claim, to facilitate and promote the trade of SAF volume credits or GHG emissions reductions

Book and claim accounting systems allow fuel off-takers, such as airlines and airports, to account for SAF's environmental benefits without the need to also possess and physically consume SAF. This means SAF does not need to be carried all the way to a specific aircraft – instead it can be delivered to a point of consumption that is closer to the production site or has more efficient logistics.

There, SAF can be physically mixed and sold as aviation fuel. The right to claim the GHG emissions reductions from the SAF consumed is traded on a separate online market in the form of certificates or credits, such as the Sustainable Aviation Fuels Certificate (SAFc)[64] framework pioneered by the Clean Skies for Tomorrow (CST) initiative.

Such a system has possible advantages, including facilitating SAF production in regions with lower production costs; minimising transport-related carbon emissions; no SAF volume restrictions for off-takers due to logistical or local production constraints. However, it requires fraud avoidance via robust associated track and trace mechanisms that cannot be circumvented. There exist concerns on the risks of fraud while avoiding associated track and trace mechanisms that impose disproportionate administrative burdens. In addition, the trade of SAF may mean that desired local benefits of SAF production do not occur.

Examples:

- Under the current SAF opt-in option in the Netherlands to comply with the EU Renewable Energy Directive (RED), the SAF use certificates can be traded (limited to a national system only).
- The USA Environmental Protection Agency Moderated Transaction System is designed to allow companies to report and track transactions for national fuel programmes, such as the Renewable Fuel Standard and Gasoline Sulphur programme.

6.5.2. Ease SAF-related imports and exports

Restrictive import and export measures to control national fuel trade streams can negatively influence the development of SAF supply chains worldwide. When nations set import barriers too high in an effort to protect domestic producers, it can exacerbate the already notable cost difference between SAF and conventional jet fuels. Other nations may have the potential to produce cost-competitive SAF beyond their national needs but choose to elevate export barriers to guarantee the use of renewable fuels within the country, providing no incentive to expand supply chains.

Easing international SAF trade will alleviate these market failures and contribute to industry decarbonisation by allowing for the sourcing of sustainable feedstocks – and the production of SAF – where it is more economically viable and environmentally sound to do so. However, the trade of SAF may mean that desired local benefits of SAF production do not occur.

Policy option 19: Reduce import barriers on SAF-related products if national production is not feasible or insufficient to meet the domestic demand

The development of SAF production chains around the world will be necessary to achieve the volumes of SAF needed to replace the use of conventional jet fuel. Some nations, however, might not be able to generate enough sustainable feedstock or SAF to cover their aviation industry emissions reduction ambitions and will, at least in the short term, need to rely on imports.

Reducing import tariffs or giving SAF and feedstocks a friendlier trade classification, such as industrial product (some countries impose higher trade barriers on products classified as agricultural)[92], can help bridge the cost differential and serve to keep national SAF production cost-competitive.

As with a virtual market place, this option comes with the negative consequence where the incentive to develop local SAF production is reduced.

Example:

- The EU currently has 41 trade agreements with 72 countries, including free trade agreements (FTAs), which enable reciprocal market opening with developed countries and emerging economies by granting preferential access to markets.

- Asia's Regional Comprehensive Economic Partnership (RCEP) is a free-trade agreement between 15 Asia-Pacific countries expected to phase out tariffs on a host of biofuels and feedstocks.

6.5.3. Adopt recognised sustainability standards, and harmonise certification

The SAF market will need to rapidly develop in the coming years to meet ambitious climate targets. There is a risk that if countries develop these markets in isolation, a patchwork of systems and certification standards will evolve, creating additional complexities, costs and delays for industry participants in production, distribution, compliance and monitoring.

Policy option 20: Adopt clear and globally or regionally recognised sustainability standards for feedstock supply

A key element of SAF sustainability certification relates to feedstock supply. Multiple SAF production pathways have demonstrated viability or are being tested now using different types of bio or synthetic feedstocks. Each feedstock produces different levels of LCA GHG emissions reductions and different sustainability considerations.

While nations may seek to determine their own sustainability criteria for feedstock, using internationally recognised standards ensures environmental integrity and can facilitate international trade, simplify emissions accounting across different geographies, and keep monitoring and compliance costs as low as possible.

Examples:

- National governments (e.g. U.S. RFS2); Regional regulators (e.g. EU RED), international bodies (e.g. ICAO CORSIA); and, industry/non-governmental organisations (e.g. Roundtable on Sustainable Biomaterials (RSB), International Sustainability and Carbon Certification (ISCC) have all developed sustainability certification and GHG emissions methodologies.

[92] Kojima, Masami et al., Considering Trade Policies for Liquid Biofuels: ESMAP Renewable Energy Special Report 004/07, 2007

- SAF compliant with the CORSIA sustainability criteria are eligible under the US Administration SAF tax credit incentives frameworks provided they achieve at least 50% life-cycle greenhouse gas emissions reduction[93].

6.5.4. Other measures to enable supply and demand connection

In addition to measures facilitating certification and stimulating SAF trading, policymakers may also consider a series of individual but equally important policy instruments to support links between supply and demand on a global level.

Policy option 21: Support SAF stakeholder initiatives

Stakeholder consultation groups can take many forms and be either government, industry or NGO led. These groups serve a critical function of aligning the diverse stakeholders that make up the SAF supply chain. They can directly coordinate actions and provide critical information and feedback to policymakers.

Example:

- Several SAF stakeholder groups have provided support to SAF promotion. These include European states' platforms (as reflected in Chapter 3.2) the Renewable and Low-Carbon Fuels Value Chain Industrial Alliance in the EU, the Commercial Aviation Alternative Fuel Initiative (CAAFI) or the Brazilian Biojetfuel Platform (BBP), among others. For a listing of the many initiatives see ICAO's Global Framework for Aviation Alternative Fuels.

Policy option 22: Support the roll-out of existing SAF production technologies and international capacity-building to developing countries to promote the adoption of SAF production globally

Aviation is a global industry with global emissions impacts; inaction in one part of the world can undermine positive steps to decarbonise elsewhere. A global effort to remove key market, technical and financial barriers to SAF development in all regions is critical.

States can support this through direct capacity-building, sharing of best practices and lessons learned from their own implementation, supporting the roll-out of commercially ready SAF production pathways, and via participation in global capacity-building initiatives.

Examples:

- The ICAO-EU Capacity-building for CO_2 mitigation from international aviation project has conducted four SAF use case studies in developing countries. At the 41st ICAO Assembly in September 2022, the European Commission and ICAO signed a declaration of intent for a project under the ICAO ACT-SAF initiative (see below).

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93 https://www.congress.gov/bill/117th-congress/house-bill/5376/text#H5392A7C300494637A0F340D54E8D26E3

- The ECAC Capacity-Building Programme for Environment provides assistance to ECAC and non-ECAC States on SAF -related training.
- The ICAO Assistance, Capacity-building and Training for Sustainable Aviation Fuels (ICAO ACT-SAF) aims to provide tailored support for States in various stages of SAF development and deployment, facilitate partnerships and cooperation on SAF initiatives around the globe.

6.6. Interaction between supply, demand and enabling measures

Any regulatory framework should stimulate supply, demand and enabling measures in a coordinated way to avoid cumulative effects from combined stimuli or a mismatch between supply and demand that interferes excessively with market equilibrium.

Mandatory policy measures must include enforcement mechanisms. Those should be sufficiently costly for economic players not fulfilling the obligations, to disincentivise paying fines versus complying.

The possibility of individual SAF projects qualifying for an array of support instruments could lead to excessive subsidies. These undesirable effects can be mitigated via anticipation of the policy impact on the value chain, adequate monitoring of market activity, and by timely adjustments of regulatory provisions when issues are identified. In general, market-driven programmes such as auctions have proven most appropriate for avoiding the pitfalls of excessive subsidisation.

A single and balanced policy framework should plan for and implement supply and demand measures, with coordination and planning for when each policy will enter into force. For example, the time period needed for SAF supply chains to mature (the average lead time from plant initiation until commercial operation is around 4 years) might lead to an imbalance between supply and demand if measures to stimulate the latter, such as blending mandates, come into force before a sufficient number of SAF plants are operational.

Section III — Key Policy Recommendations

This SAF Guidance devotes its Section III to recommendations for ECAC States to develop harmonised SAF policies and identifies different policy options or combinations of policies which can be used to support the development of a large-scale SAF market.

The main key policy recommendations include:

Create national SAF strategies and implementation plans

Before implementing SAF policies, it is recommended to first develop a coherent national SAF strategy, which should start by gathering data and analysing the context of each country, including among others, feedstock and industrial potentials, existing and planned policy frameworks and regulations, and the identification of key stakeholders present on national territory or subject to national administration.

Those national strategies can be framed in wider regional and global policies or regulatory frameworks. Benchmarking the national context with respect to regional (e.g. European Green Deal, Destination 2050) and global visions (e.g. LTAG, Waypoint 2050) can help exploring the national potentials.

Holistic decarbonisation strategies that embrace all transport modes and available technology options maximise emission reductions across sectors.

Creating national multistakeholder platforms is a recommended practice which has been a successful tool in pioneering European States to facilitate debate and engage different involved public departments, industry, civil society, and other key players.

Effective SAF policies embrace the expertise and capabilities of feedstock producers, fuel producers and suppliers, original equipment manufacturers, airports, and airlines. They also promote stakeholder consultation and involve local communities in projects.

Set targets and create predictability to mobilise investments

Medium to long-term policy and regulatory predictability is key to influence market expectations and incentivise investments. That can be provided by setting a national policy vision which includes the definition of targets and ambitions.

Even if moderate in its initial stages, those targets can raise industry’s interest in making the necessary investments to enable further gradual increase of ambitions and scale up SAF supply along the time. Targeted policies to provide predictability, reduce costs, and increase production volumes, are necessary to sustain early market growth.

While later adjustments may be needed, steady initial steps and ambitions should be firm to keep regulatory certainty and promote resources mobilisation.

It is encouraged to align the vision and targets with the ICAO Long-Term Aspirational Goal (LTAG) of reaching net-zero CO_2 emissions from international aviation by 2050. Short-term action is fundamental to achieve those goals, so all States are encouraged to take early action.

Developing national SAF feasibility studies is another good practice which has helped States to understand national potentials and set the basis to propose implementation roadmaps.

Develop national SAF roadmaps or transition pathways

Achieving the defined goals requires developing appropriate policies, regulations, and incentives to support SAF commercial production and supply while ensuring its economic long-term viability and competitiveness.

Creating roadmaps or transition strategies has been another very valuable common practice in pioneering European States, in most cases framed in wider national climate policies and objectives. Its main final purpose should be informing policymakers on the necessary actions that are needed to incentivise SAF and mobilise investments into SAF research, development, and pilot production.

Market competition with other regions and sectors need to be considered, especially with respect to feedstock production and supply. It is recommended to include in national roadmaps the development of supply chains for sourcing of sustainable biomass and renewable feedstock and electricity from local and regional producers, stimulating local economies and maximising supply chain logistics efficiencies.

It is essential to ensure a level playing field across the European air transport market, when it comes to the use of aviation fuel and thus, promotion of SAF should not generate aviation market distortions.

Barriers or distortion to competition in the SAF production value-chain, logistics and use should also be avoided.

Establish a sustainability framework with credible emission reductions and build social trust

Any SAF strategy should be based on ensuring its environmental and social integrity and supply chain verification, especially with respect to selecting sustainable feedstocks, to maximise emission reductions and prevent unintended impacts, including environmental and socio-economic negative effects.

It is strongly encouraged that SAF strategies developed in ECAC Member States will ensure that SAF complies with globally or regionally recognised robust sustainability frameworks (such as the ICAO CORSIA) to safeguard credible emission reductions and ensure building trust of civil society.

Harmonisation of compliance requirements across Member States at European level and as much as possible at global level, will help avoiding barriers for SAF deployment and use.

To maximise climate benefits, it is also recommended that SAF targets focus on the quantity of avoided CO_{2eq} emissions rather than only on the volume of SAF produced or supplied.

Avoiding any misleading information and communication strategies related to SAF use and trading as well as avoiding fraud are necessary as well to build trust in the benefits of SAF use.

Select the most suitable policy or combination of policy options

The most suitable policies to promote SAF are likely to vary for each country according to their geographic, economic, social and political characteristics.

No individual policy will drive SAF growth on its own. A range of supply, demand and enabling policy instruments aligned to each country's circumstances in terms of feedstock availability, value chain maturity, energy dependency, and climate goals need to be planned and implemented in a coordinated way.

Policy-makers are invited to use the information contained in Chapter 6 of this Guidance to support decision-making regarding policy options to be used and help conducttheir own cost-benefit and regulatory impact analysis.

Eight qualitative metrics extracted from the ICAO *Guidance on potential policies and coordinated approaches for the deployment of SAF*, can also be used by States for assessing policy effectiveness and identify potential policies which have been demonstrated to be feasible, effective, and practical, the three key parameters influencing policy effectiveness.

It is necessary to seek a balance between demand side policies (e.g. mandates) and measures on the supply side (e.g. incentives, funding) to preserve market equilibrium and avoid possible carbon leakage, where aviation markets would move from a country with stringent policies, to a country that is more lenient, leading to an overall increase in greenhouse gas emissions.

While SAF policies can incentivise certain advanced technology pathways, such as SAF produced from sources of non-biological origin, it is recommended to set policies which ensure sustainability but are technology-neutral to enable diverse production pathways and supply chains to develop.

Stimulating growth of SAF supply can be achieved via:

- funding and promoting SAF Research, Development and Demonstration;
- de-risking first-of-a-kind SAF production plants;
- supporting the expansion of SAF infrastructure and high technology readiness level pathways;
- prioritising feedstock for SAF production & optimising conversion yields; and
- stimulating sustainable feedstock and valorising SAF benefits

Stimulating SAF uptake can be done, among other options, via:

- updating existing national policies and creating SAF blending mandates;
- incorporating social and environmental costs to conventional jet fuel; and
- demonstrating government leadership and including SAF in public procurement

Additional policy measures can facilitate SAF markets with measures such as:

- establishing flexible logistic mechanisms for the SAF transition and virtual SAF marketplaces;
- supporting SAF stakeholders' initiatives;
- capacity-building to promote the adoption of SAF production globally; and
- including adequate enforcement mechanisms.

Ideally, a single and balanced policy framework should plan for, and implement, supply and demand measures, with coordination and planning for when each policy will enter into force.

7. Conclusion

The present guidance was developed by the ad-hoc Sustainable Aviation Fuels Task Group (SAF-TG), endorsed by the European Aviation and Environment Working Group (EAEG) Expanded and adopted by Directors General of ECAC States.

It is addressed to ECAC States which might consider developing SAF promotion policies for the first time, as well as to those which are already in the process of implementing them and might wish to promote harmonised implementation approaches across Europe.

The main purposes of this guidance are:

(i) to promote technical understanding of what are sustainable aviation fuels and why they are needed to decarbonise aviation;

(ii) to identify possible barriers for SAF promotion and SAF potentials for European States;

(iii) to share information about the current policies developed, or under development, in different European States and at European Union level;

(iv) to provide a wide overview of possible policy options to support SAF promotion in ECAC States; and

(v) to provide best practices and key policy recommendations to set harmonised implementation approaches.

The information contained in this document will be the foundation for ECAC capacity-building activities to support ECAC Member States to set national policy actions and roadmaps to accelerate the development and use of SAF, and to include them in the next update of their State Action Plans to reduce CO_2 emissions from international aviation.

Glossary

ASTM: American Society for Testing and Materials, is the current global reference standard for new SAF specifications. Specification D1655 is a globally recognised standard for Jet A-1. The ASTM D7566 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons is the current global reference standard for SAF.

Blend-stock: A fuel component that is either certified to be used as aviation fuel or is blended with other components to be certified.

CAEP: ICAO Committee on Aviation Environmental Protection.

Capacity-building: In the context of climate change, the process of developing the technical skills and institutional capability in developing countries and economies in transition to enable them to address effectively the causes and results of climate change.

Carbon leakage: Refers to a situation where aviation markets would move from a country with stringent policies, to a country that is more tolerant, leading to an increase in greenhouse gas emissions.

Clearing house: A service which facilitates and simplifies transactions among multiple parties.

CO_2: Carbon dioxide.

CORSIA: ICAO Carbon Offsetting and Reduction Scheme for International Aviation.

DEF STAN 91-091: Defence Standard 91-091 is a European reference Standard for aviation turbine fuel, which the United Kingdom Civil Aviation Authority (CAA) has agreed is under the technical authority of the Defence Strategic Fuels Authority (DSFA).

EAER: European Aviation Environmental Report. Published by EASA every three years, the core aim of the report is to provide an objective, clear and accurate source of information on the environmental performance of the aviation sector at the European level. It also reports on actions being put in place to drive forward sustainability ambitions, and contains recommendations on how the level of environmental protection could be improved.

EASA: European Union Aviation Safety Agency.

ECAC: European Civil Aviation Conference.

Emissions Trading System (ETS): A market mechanism that allows those bodies (such as countries, companies or manufacturing plants) which emit (release) greenhouse gases into the atmosphere, to buy and sell these emissions (as permits or allowances) amongst themselves.

EUROCONTROL: European Organisation for the Safety of Air Navigation.

European Commission: The European Union's politically independent executive arm. It is alone responsible for drawing up proposals for new European legislation, and it supports EU Member States in the implementation of the decisions of the European Parliament and the Council of the EU.

European Union (EU): An economic and political union between 27 European countries. Members are Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.

EU ETS: European Union Greenhouse Gas Emissions Trading System. More information can be found in this link: https://climate.ec.europa.eu/eu-action/transport-emissions/reducing-emissions-aviation_en

Federal Aviation Administration (FAA): Is an operating mode of the U.S. Department of Transportation and regulates all aspects of civil aviation in the country.

Feedstocks: Raw materials that are used to produce something in an industrial process.

Fischer–Tropsch (FT) synthesis: Is a heterogeneous catalytic process that converts biomass-derived syngas (mixture of CO and H_2) to synthetic liquid fuels and valuable chemicals.

Greenhouse gases (GHG): The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent --but very powerful -- greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

ICAO: International Civil Aviation Organization.

Life-cycle assessment (LCA): Is a process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform. In the context of SAF if usually refers to the assessment of GHG emissions over the entire lifecycle. See ISO 14040-44.

LTAG: Collective **Long-Term global Aspirational Goal** for international aviation of net-zero carbon emissions by 2050 in support of the UNFCCC Paris Agreement's temperature goal, adopted by the 41st Assembly of the International Civil Aviation Organization (ICAO) in 2022.

LCAF: **Lower Carbon Aviation Fuels** is a terminology that has only emerged in ICAO context. An LCAF is by the ICAO CORSIA SARPs as *a fossil-based aviation fuel that meets the CORSIA Sustainability Criteria under ICAO Annex 16 Volume IV*.

LCF: **Low-carbon fuels.** Although the terminology is widely spread around the world, there is not one single standard definition, and each jurisdiction determines its own standards, depending on its objectives. These fuels are defined by the European Fuel Industry (Fuels Europe) as *sustainable fuels of non-fossil origin unlike conventional fuels made from petroleum. They emit no or very little additional CO2 during their production and use*.

The terminology of "synthetic low-carbon fuels for aviation" is also currently being defined by the EU under the ReFuelEU regulatory negotiations. The definition proposed by the EU Presidency in ReFuelEU negotiations is: *synthetic low-carbon fuels for aviation' means synthetic drop-in aviation fuels derived from non-fossil low-carbon hydrogen whose life-cycle GHG emissions savings from their use are at least 70%;*

Net zero carbon or Net zero CO_2: Is defined by the IPCC, the United Nations body for assessing the science related to climate change, as: "*When anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period*", meaning *anthropogenic* in the context of greenhouse gases, emissions that are produced or removed as the result of human activities.

Pathway: A SAF production technology comprising a specific conversion process and the associated feedstock (*Reference: ICAO document - CORSIA Eligibility Framework And Requirements For Sustainability Certification Schemes*).

Syngas: or synthesis gas, is a mixture of hydrogen and carbon monoxide, in various ratios.

Synthetic aviation fuels: Fuels that are renewable fuels of non-biological origin, as defined in Article 2, second paragraph, point 36 of Directive (EU) 2018/2001, used in aviation. This is explained in the impact assessment to the ReFuelEU Aviation regulatory proposal (COM(2021) 561 final, Page 135, Annex 15 – SAF Production Routes) as "*sustainable aviation fuels based on non-biologic origin (RFNBOs), where the source of energy is not based on crops, or residues or waste, but obtained from renewable electricity*".

Synthetic fuels are also commonly denominated as electro-fuels, e-Fuels, Power-to-Liquid (PtL) or aviation fuels with significant electricity inputs, and in other jurisdictions can have a different definition and feedstock sources such as industrial gasses (also called recycled carbon).

For example in the US., the terminology has a very different meaning: On its Annual Energy Outlook 2006, the US Energy Information Administration (EIA) defines synthetic fuels as *fuels produced from coal, natural gas, or biomass feedstocks through chemical conversion into synthetic crude and/or synthetic liquid products*[94]*.*

Synthetic Paraffinic Kerosene (SPK): is an aviation turbine fuel containing synthesised hydrocarbons.

Tankering: occurs when aircraft operators uplift more aviation fuel than necessary at a given airport, with the aim to avoid refuelling partially or fully at a destination airport where aviation fuel is more expensive.

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